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Revision 0

Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State-Approved Land Disposal Site, Fiscal Year 2010

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

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Richland, Washington 99352

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Program/Project: S&GRP

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Executive Summary

The Hanford Site's 200 Area Effluent Treatment Facility (ETF) processes contaminated aqueous wastes derived from Hanford Site facilities. The treated wastewater occasionally contains tritium, which cannot be removed by the ETF prior to discharge of the wastewater to the 200 Area State-Approved Land Disposal Site (SALDS). During the first 10 months of fiscal year (FY) 2010 (October 1, 2009, to September 30, 2010), approximately 48.0 million L (12.7 million gal) of water containing 2.42 Ci of tritium were discharged to the SALDS. Groundwater monitoring for tritium and other constituents, as well as water-level measurements, is required for the SALDS by *State Waste Discharge Permit Number ST-4500* (Ecology, 2000).

The current monitoring network consists of three proximal (compliance) monitoring wells and nine tritium-tracking wells (including one well co-located with a piezometer that is sampled separately). Quarterly sampling of the proximal wells occurred in October 2009 and in February, May, and July 2010. The nine tritium-tracking wells, including groundwater monitoring wells located upgradient and downgradient of the SALDS, were sampled in October 2009 and in January, February, March, April, June, and July 2010, with at least one sample collected in each month.

Water-level measurements taken in the three proximal SALDS wells indicated that a small groundwater mound is present beneath the facility, which resulted from operational discharges. The mound remained relatively stable from the previous year and reflects increased ETF discharges from treating groundwater from extraction wells at the 200-UP-1 Operable Unit (OU) and the T Tank Farm. The ETF discharges in FY 2010 did not include waste from the treatment of 242-A evaporator condensate, as in some previous periods, but did include 6.8 million L (1.8 million gal) discharged in August and September from treatment of high-tritium K Basins and Environmental Restoration Disposal Facility (ERDF) leachate wastewater. Waste treated by the ETF during FY 2010 was primarily from the 200-UP-1 and 200-ZP-1 OUs and K Basins/ERDF leachate, although small quantities of Mixed Waste Burial Trench leachate and well purgewater were also treated.

Maximum tritium activities decreased at well 699-48-77A, from the FY 2009 maximum of 77,000 pCi/L (January 2009) to a FY 2010 maximum of 9,600 pCi/L (October 2009). This decrease is due to a decrease in tritium concentrations in the ETF effluent.

The additional tritium discharged in August and September 2010 will be seen in future sampling. The maximum FY 2010 tritium activity at proximal well 699-48-77C was 76,000 pCi/L (July 2010), which was effectively unchanged from the FY 2009 maximum of 64,000 pCi/L. Well 699-48-77D showed an increase in tritium activity with a FY 2010 maximum (October 2009, February and July 2010) of 180,000 pCi/L when compared to the FY 2009 maximum of 110,000 pCi/L. This increase in activity can be attributed to higher concentration material from discharges in FY 2006 and FY 2007 reaching the well.

To date, no indications of a tritium incursion from the SALDS have been detected in the tritium-tracking wells. Regional water-level declines are beginning to impact the monitoring well network to the point where installation of replacement wells is now an issue of concern. Concentrations of all chemical constituents were within Permit limits or were below method detection limits during FY 2010 sampling.

Reactive transport modeling performed in FY 2010 (described in Chapter 4) suggests that tritium concentrations at some monitoring wells located along the northern margin of the 200 West Area may have measurable concentrations of tritium by 2015 and could have concentrations that approach the drinking water standard (20,000 pCi/L) by 2025.

Contents

Appendices

Figures

Tables

Terms

ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
FY	fiscal year
gpm	gallons per minute
LERF	Liquid Effluent Retention Facility
LLBG	Low-Level Burial Grounds
OU	operable unit
SALDS	State-Approved Land Disposal Site

1 Introduction

Treated water from the Hanford Site's 200 Area Effluent Treatment Facility (ETF) is discharged to the 600-211 State-Approved Land Disposal Site (SALDS) as allowed by *State Waste Discharge Permit Number ST-4500* (Ecology, 2000). The Permit allows disposal of ETF effluents to the drain field, located 360 m (1,200 ft) north of the 200 West Area (Figure 1-1). In accordance with the Permit, groundwater in the vicinity of the SALDS is routinely sampled for tritium, and water-level measurements are collected. Gross alpha, gross beta, strontium-90, and tritium do not have assigned enforcement limits but are monitored and reported for informational purposes. The Permit also requires submittal of an annual tritium-tracking report, as well as a groundwater monitoring plan that was prepared during the Permit cycle. The current plan (PNNL-13121, *Groundwater Monitoring and Tritium-Tracking Plan for the 200 Area State-Approved Land Disposal Site*) provides additional guidance for selecting and reporting groundwater analyses. The results of groundwater sampling and analysis are also reported in quarterly discharge monitoring reports. The quarterly reports for fiscal year (FY) 2010 include the following:

- "Quarterly Discharge Monitoring Reports for the 200 Area Effluent Treatment and Treated Effluent Disposal Facilities Covering the April 2010 Through June 2010 Reporting Period," Letter No. CHPRC-1000579 (Kembel, 2010a).
- "Quarterly Discharge Monitoring Reports for the 200 Area Effluent Treatment and Treated Effluent Disposal Facilities Covering the January 2010 Through March 2010 Reporting Period," Letter No. CHPRC-1000369 (Kembel, 2010b).
- "Quarterly Discharge Monitoring Reports for the 200 Area Effluent Treatment and Treated Effluent Disposal Facilities Covering the October 2009 Through December 2009 Reporting Period," Letter No. CHPRC-1000074 (Kembel, 2009a)
- "Quarterly Discharge Monitoring Reports for the 200 Area Effluent Treatment and Treated Effluent Disposal Facilities Covering the July 2009 Through September 2009 Reporting Period," Letter No. CHPRC-0900680 (Kembel, 2009b).

1.1 Objective and Scope

This report presents the results of groundwater monitoring and tritium-tracking sampling from the SALDS facility during FY 2010. Due to the 30-day laboratory turnaround for analysis of proximal well groundwater samples, this report addresses available data from October 1, 2009, through July 31, 2010. Updated background information that is necessary to understand the results of the groundwater analyses is also provided in this report. Interpretive discussions and recommendations for future monitoring are also provided where possible.

1.2 Background

Background information presented in this section is based on PNNL-13121. New information on hydrogeology, modeling comparison, and discharges is also provided, when available.

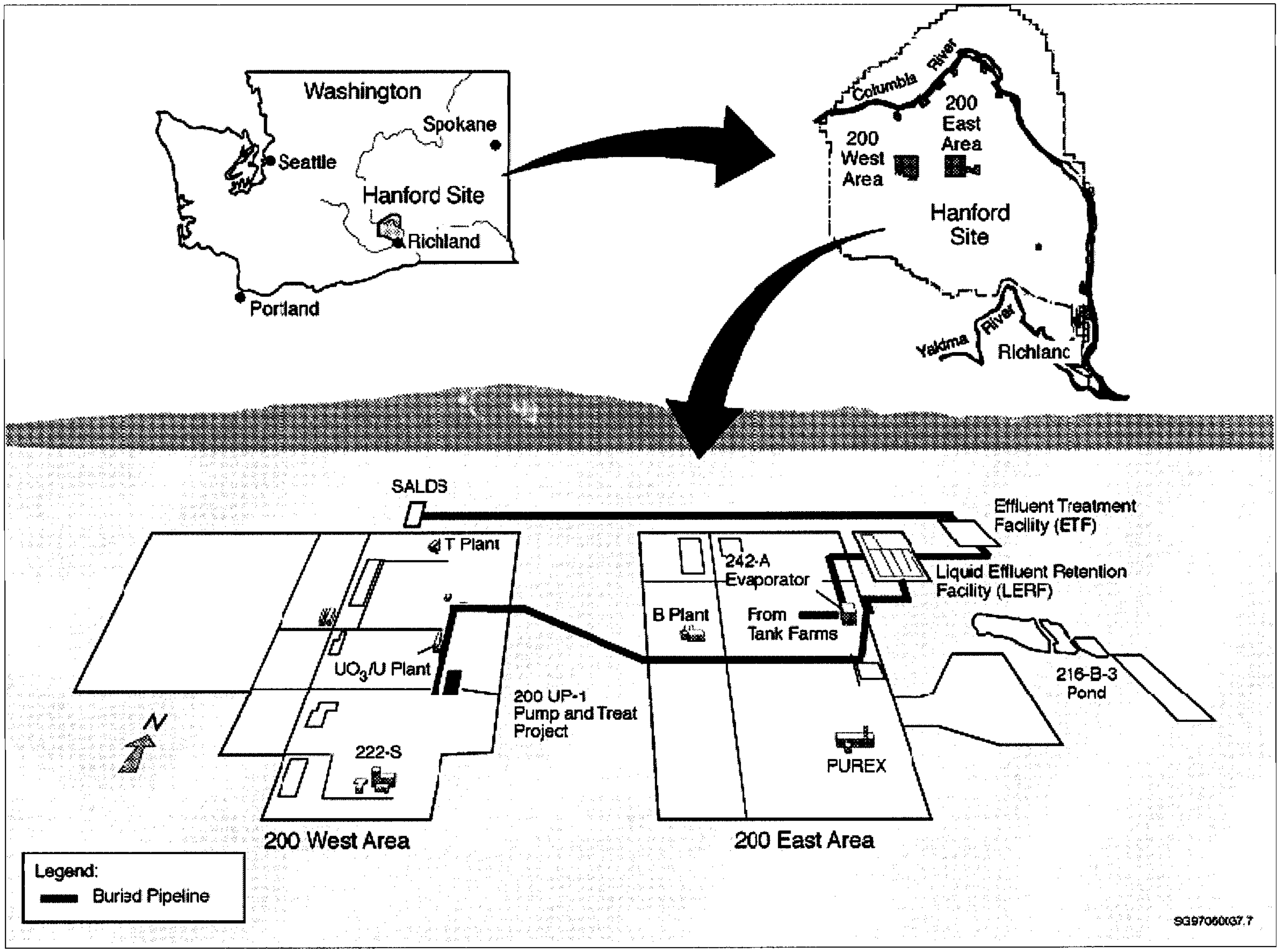


Figure 1-1. Location of the SALDS and Related Infrastructure

The primary requirements of the Permit are that a groundwater monitoring plan must undergo regulatory agency review and that tritium results (shown in Appendix A) must be compared annually with model predictions. These comparisons are presented in Chapter 3. The groundwater monitoring plan includes the following objectives:

- Track changes in groundwater quality associated with the SALDS discharges
- Determine why changes (if any) have occurred
- Track the migration rate of tritium in groundwater originating from the SALDS
- Compare model predictions with observed results for the purpose of refining predictive model capability
- Correlate discharge events at SALDS with analytical results from groundwater monitoring
- Ensure that groundwater data are accurately interpreted.

The groundwater monitoring well network (Figure 1-2) was designed to address these objectives using the existing wells shared with other nearby facilities (e.g., the Low-Level Burial Grounds [LLBG]) and dedicated wells drilled specifically for SALDS monitoring.

1.2.1 Hydrogeologic Setting and Conceptual Model

The hydrogeologic setting and the conceptual model for the SALDS have been described in previous documents (e.g., SGW-38802, *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State-Approved Land Disposal Site, Fiscal Year 2008*) and are not repeated here. Figure 1-3 shows the conceptual diagram discharge migration through the sediment profile to groundwater at the SALDS.

1.2.2 Groundwater Modeling

The Permit requires running an updated numerical groundwater model at least once during a 5-year Permit cycle to predict tritium movement and the distribution of tritium in the aquifer as a result of SALDS discharges. The Permit also requires that the model be reapplied "within 6 months of detection of the tritium plume in a new monitoring well." This requirement indicates that the numerical model will be reapplied when the tritium plume associated with the SALDS is positively identified in a location not predicted by the most recent model run, or within a well not previously affected by an incursion of SALDS-derived tritium. To date, no positive indications of tritium incursion have been detected in a new monitoring well.

The most recent groundwater model application, conducted in 2010, is summarized in Chapter 4, and a more complete description of the model application is provided in Appendix B. The model output graphically illustrates the predicted head distribution and tritium concentrations in groundwater near the SALDS for selected timeframes between 2000 and 2030. The model incorporates recent refinements to the Hanford Sitewide groundwater model (DOE/RL-2009-38, *Description of Modeling Analyses in Support of the 200-ZP-1 Remedial Design/Remedial Action Work Plan*) and the water volume and tritium release information reported through July 2010.

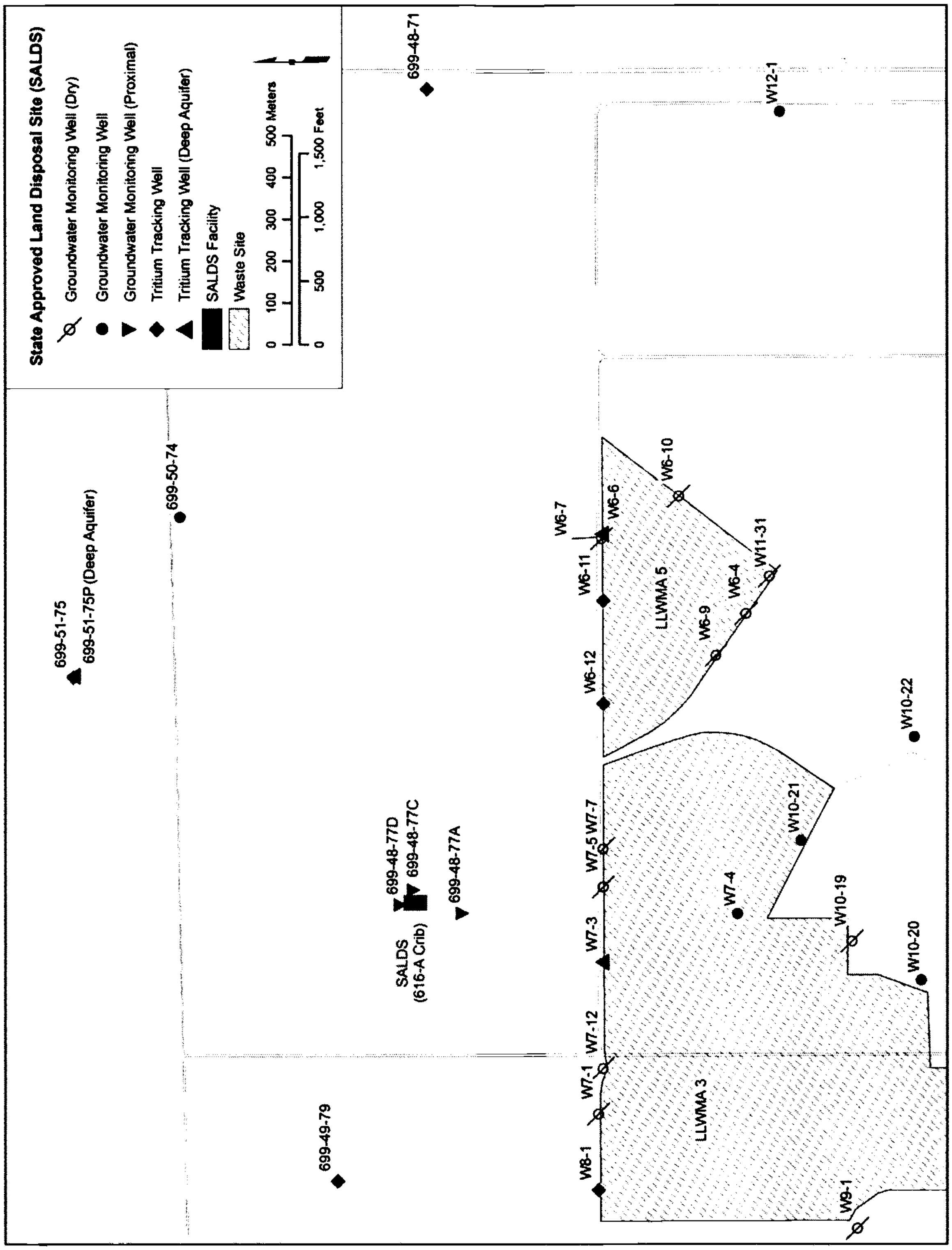


Figure 1-2. Locations of SALDS Groundwater Monitoring and Tritium-Tracking Network Wells

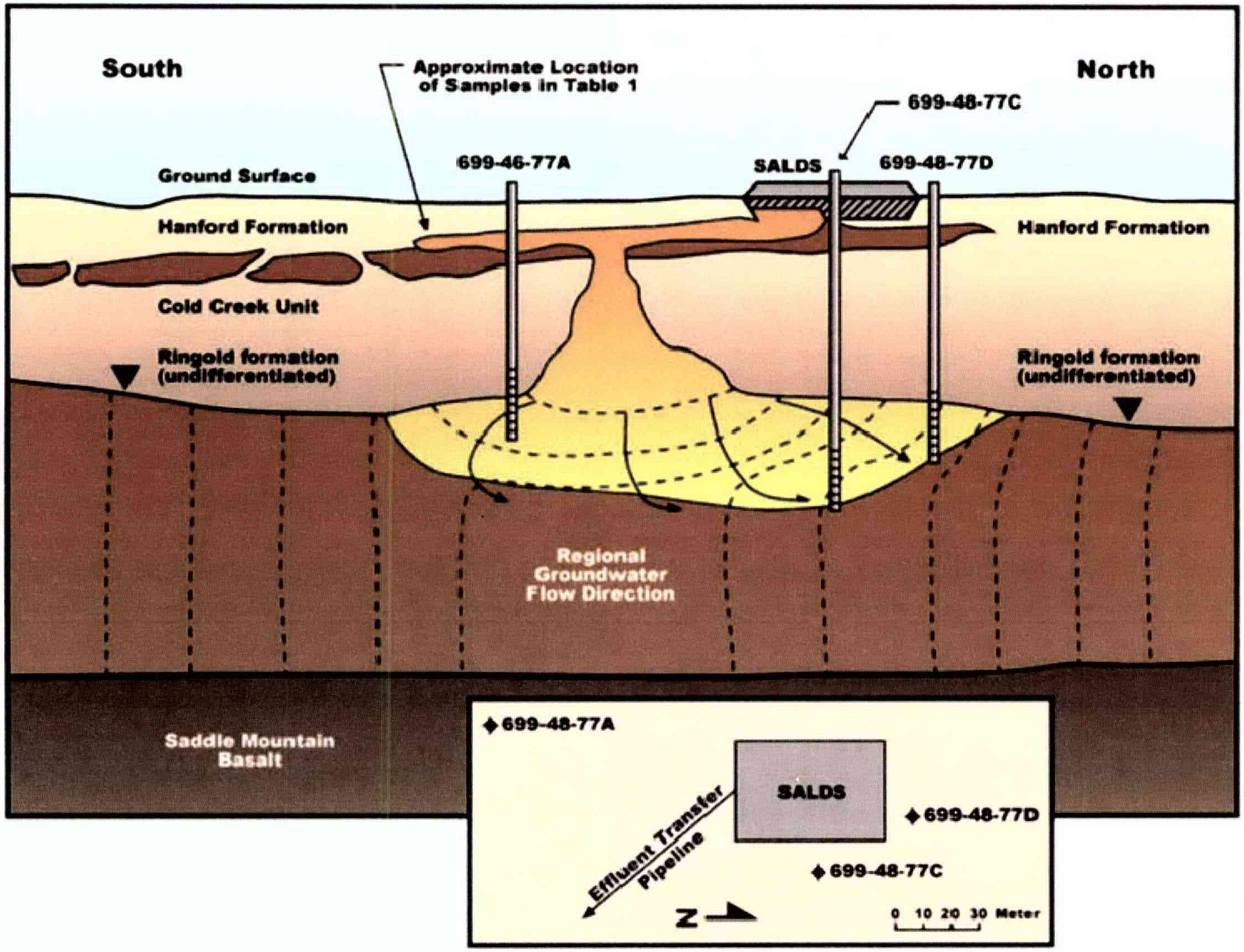


Figure 1-3. Conceptual Diagram of SALDS Operational Effects

1.2.3 SALDS Discharge Information

The SALDS effluent infiltration gallery (i.e., 619-A Crib) is a 35 m by 61 m (116-ft by 200-ft) rectangular drain field with 4-in.-diameter porous pipe laterals coming from an 8-in.-diameter header at 1.8 m (6-ft) intervals. The drain field pipes are 15.2 cm (6 in.) below the surface of a 1.8 m (6-ft)-deep gravel basin. The gravel basin is covered by a minimum of 30.5 cm (12 in.) of natural, compacted cover soil.

Discharge of tritium-laden water to the SALDS began in December 1995, with 220 Ci of tritium released in the first 6 months (about 53 percent of the total inventory released to date). Discharge volumes until FY 2004 were about 95 million L (25 million gal) each year. Discharges between March 2005 and August 2007 were sporadic and included intermittent campaigns to treat 242-A evaporator process condensate and K Basins project waste streams, which supplied much of the tritium recently discharged to the SALDS. Discharge volumes have increased since September 2007 (to FY 2004 levels) when the ETF began treating wastewater from the 200-UP-1 Operable Unit (OU) and the T Tank Farm; however, the tritium activity is low in these streams.

During the first part of FY 2010 (October 2009 through September 2010), approximately 48.0 million L (12.7 million gal) of water were discharged to the SALDS, compared to approximately 70.6 million L (18.6 million gal) during the same period in FY 2009. The primary sources of FY 2010 effluent were from low-tritium-bearing groundwater streams from pump-and-treat systems at the 200-UP-1 OU and the T Tank Farm in the 200-ZP-1 OU. The ETF treated K Basins and Environmental Restoration Disposal Facility (ERDF) leachate wastewater in August and September 2010. The tritium concentration is much higher in this stream. The highest discharge to the crib between October 2009 and September 2010 occurred in April 2010, when 10.2 million L (2.68 million gal) were received. No discharges from ETF to the SALDS took place in October through November 2009 (first quarter of FY 2010) due to replacement of the thin-film dryer rotor at the ETF; also, no discharges were made in June 2010 due to another replacement of the rotor. Total discharge volume to the SALDS since December 1995 is greater than 1,030 million L (273 million gal) (Figure 1-4).

During FY 2010, the 200-UP-1 OU pump-and-treat system pumped groundwater to the Liquid Effluent Retention Facility (LERF) Basin 43 at average rates ranging between approximately 4.0 L/min (1.1 gallons per minute [gpm]) and 14.8 L/min (3.9 gpm). The lower rate is the average rate for the first quarter of FY 2010, and the higher rate is for the third quarter of FY 2010. The 200-UP-1 OU pump-and-treat system did not discharge to the LERF during the second quarter of FY 2010. Groundwater from two wells near the T Tank Farm was also sent to LERF. The pumping rate from this facility increased during each of the first three quarters of FY 2010, averaging 27.6 L/min (7.3 gpm) in the first quarter, 74.9 L/min (19.8 gpm) in the second quarter, and 102.4 L/min (27.1 gpm) in the third quarter. The ETF treated approximately 6.8 million L (1.8 million gal) of K Basins/ERDF leachate and miscellaneous wastewater in FY 2010, which had been combined and stored in LERF Basin 44 for several years. The volume of each source is approximately as follows:

- K Basins wastewater: 2.35 million L (622,000 gal)
- ERDF leachate: 2.88 million L (760,000 gal)
- Mixed Waste Burial Trench leachate: 0.38 million L (100,000 gal)
- Purgewater/ModuTank™[1] water: 1.10 million L (291,000 gal).

[1] ModuTank™ is a trademark of ModuTank Inc., Long Island City, New York.

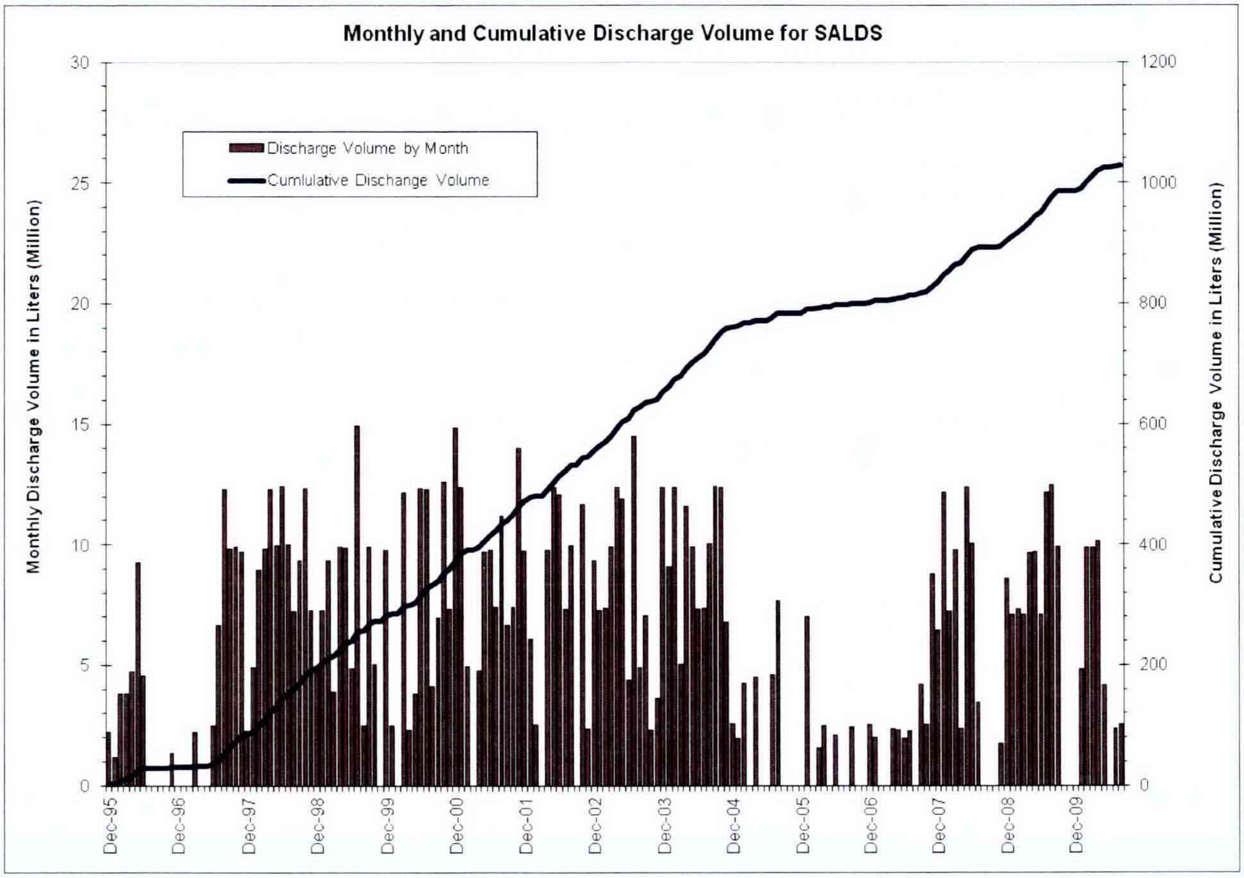


Figure 1-4. Monthly and Cumulative Discharge Volumes for the SALDS from Inception Through July 2010

The total quantity of tritium discharged to the SALDS during FY 2010 (October 2009 through mid-August 2010) was 2.42 Ci based on sampling at the ETF prior to discharge. This reflects the low concentration of tritium in the waste streams being treated. The total amount of tritium discharged to the SALDS from December 1995 through mid-August 2010 was approximately 416 Ci. Monthly and cumulative quantities of tritium discharged to the SALDS are presented in Figure 1-5.

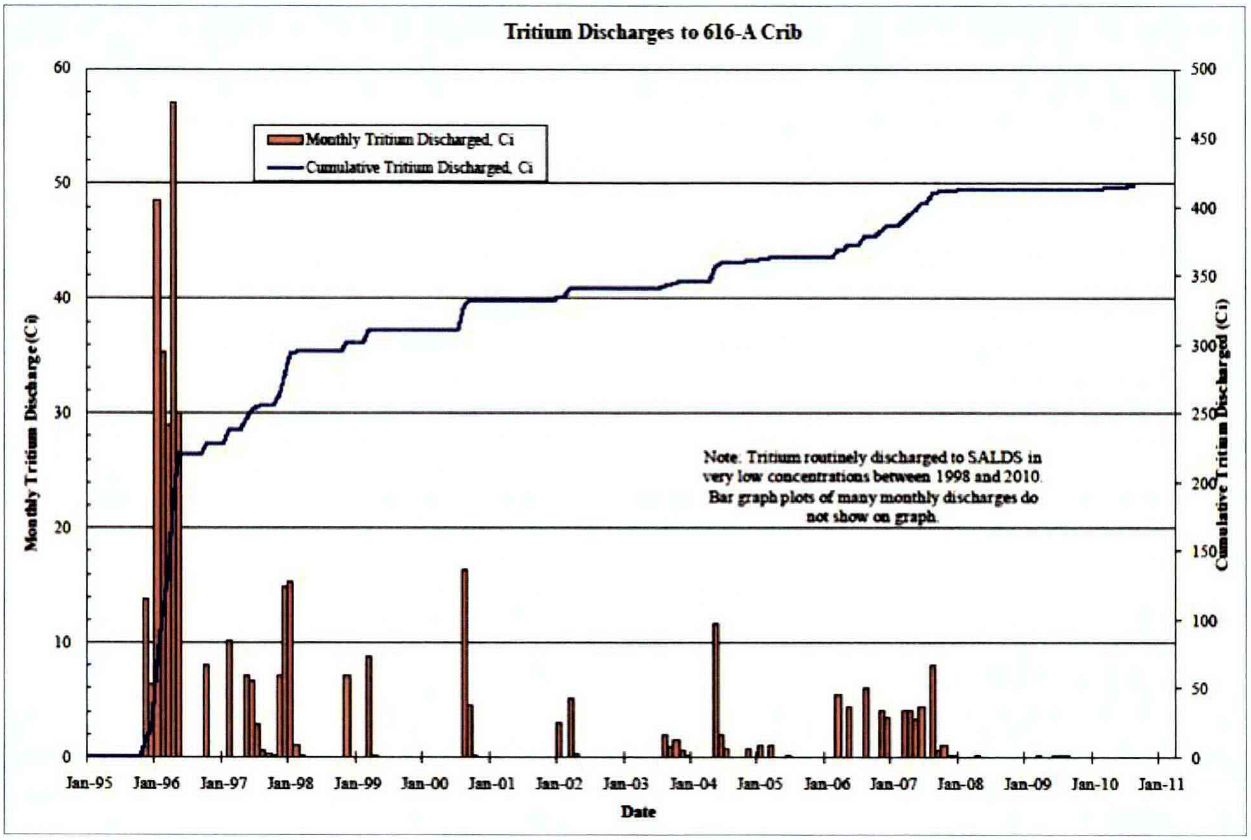


Figure 1-5. Monthly and Cumulative Tritium Curies Discharged to the SALDS from Inception Through July 2010

2 Results of FY 2010 Water-Level Measurements

Measurements of water levels in wells surrounding the SALDS are necessary to interpret the local and regional water table elevations and the groundwater flow direction. These measurements are used in combination with groundwater chemistry analyses to update conceptual and predictive models to forecast possible movement of tritium from the SALDS facility.

2.1 Measurement Results and Hydraulic Head Distribution

The following sections discuss the water-level measurements and results, as well as groundwater flow, for FY 2010.

2.1.1 Water-Level Measurements and Results

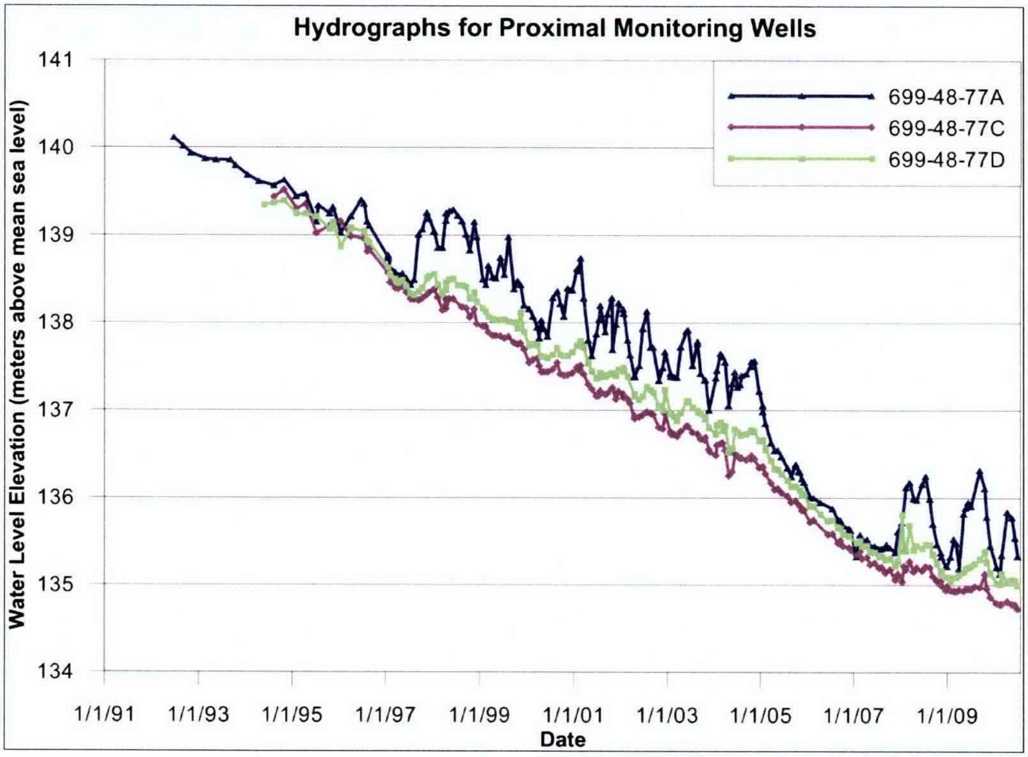
Water levels are measured in all wells prior to each sampling event and are measured monthly in the proximal SALDS wells (699-48-77A, 699-48-77C, and 699-48-77D). Proximal and tritium-tracking wells are also sampled for other programs, including the LLBG and the 200-ZP-1 OU groundwater interest area. Water levels in some wells may be measured several times per year.

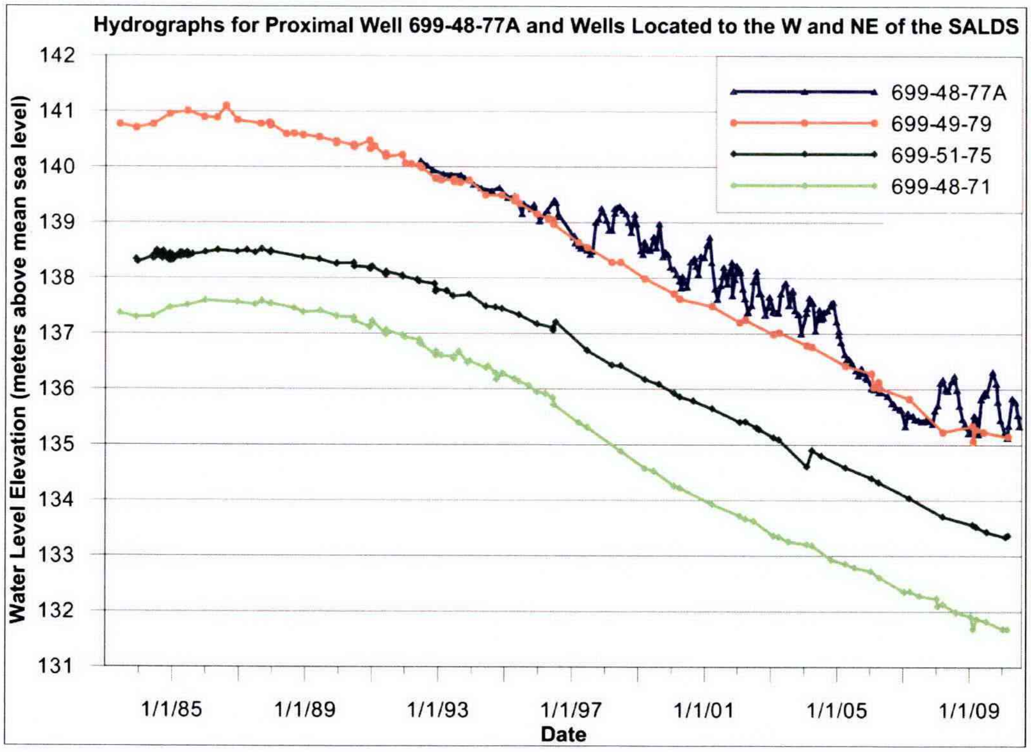
Water levels have declined in recent years to the point where a number of tritium-tracking wells no longer intersect the groundwater table (see Section 3.1). As this occurs, water-level measurements and sampling in these wells are discontinued.

Current hydrographs through July 2010 for the SALDS proximal wells and tritium-tracking network are presented in Figures 2-1, 2-2, and 2-3. Wells depicted on these hydrographs are grouped by relative position to the SALDS. All of the wells in the 200 West Area have displayed a general water table decline since surface discharges associated with process operations were terminated at U Pond in 1985 and later at all non-permitted facilities in 1995.

Most water-level readings in active wells were collected in March 2010. Using all available data, the average decline of the water table in the SALDS area between March 2009 and March 2010 was calculated to be 0.18 m/yr (0.58 ft/yr), as shown in Table 2-1. This average rate of decline includes water levels at the three proximal wells at the SALDS. Since a groundwater mound is generally present beneath the SALDS due to pump-and-treat activity, the average rate of decline may be biased by water-level elevations measured in the proximal wells. A less-biased rate of decline can be calculated by not considering the water-level changes in the proximal wells. This calculation (Table 2-1) shows that the average rate of decline of the water level in the area around the SALDS is 0.21 m/yr (0.68 ft/yr), which is somewhat lower than the average calculated for the previous 12 months (0.32 m/yr [1.05 ft/yr]).

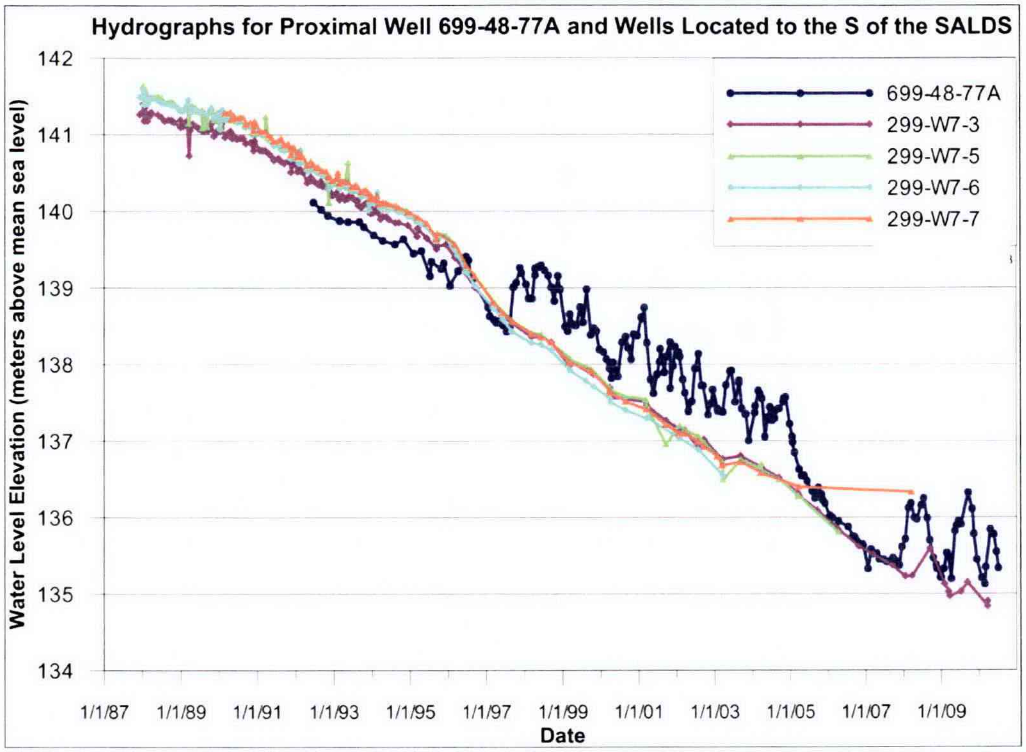
A groundwater mound centered on well 699-48-77A was observed in March 2009 at the SALDS and continued to be evident in March 2010 (Figure 2-4), even though the regional water table continued to decline during FY 2010. Mounding was also observed in proximal wells 699-48-77C and 699-48-77D. Although well 699-48-77A is located upgradient of the SALDS, it has generally had a higher hydraulic head than surrounding wells due to movement of the discharge water along the Cold Creek unit.
The mound was due to an increased treatment and discharge rate at the ETF (largely due to the addition of groundwater from two extraction wells at the T Tank Farm) and a resulting greater rate of discharge to the SALDS. During March 2010, the water level in well 699-48-77A was between approximately 0.5 m (1.6 ft) and 0.2 m (0.7 ft) higher than in proximal wells 699-48-77C and 699-48-77D, respectively.





Note: Well 699-48-77C is completed (screened) approximately 20 m (65.6 ft) deeper within the aquifer than the other two proximal wells.

Figure 2-1. Hydrographs of SALDS Proximal Wells (Top) and Tritium-Tracking Wells North, Northwest, and East of the Site (Bottom) Compared with Well 699-48-77A



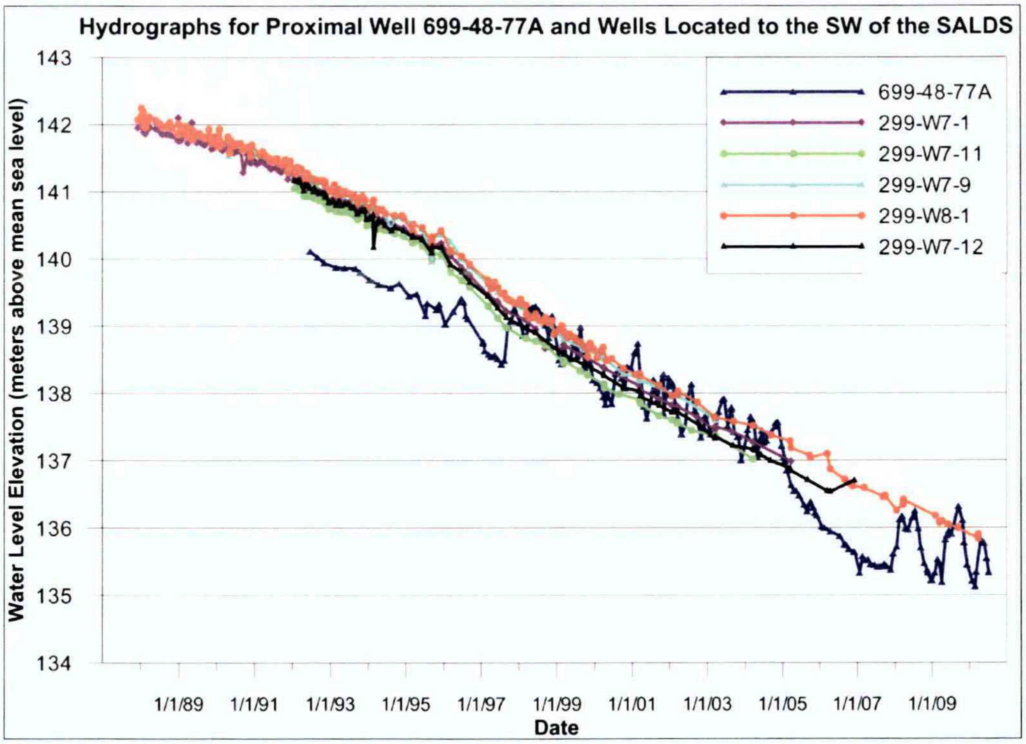
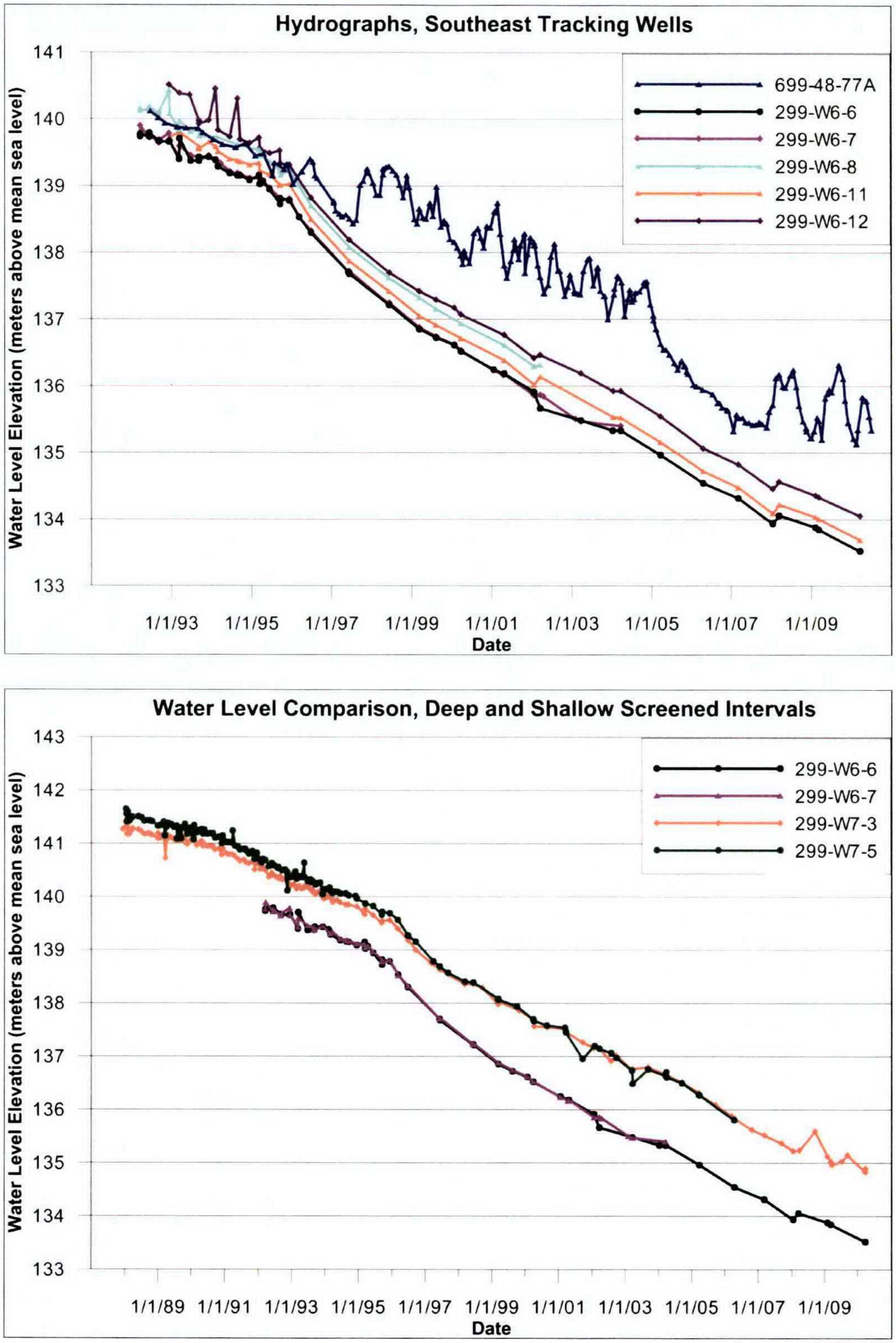


Figure 2-2. Hydrographs of Tritium-Monitoring Wells South (Top) and Southwest (Bottom) of the SALDS Compared with Well 699-48-77A



Note: Well 299-W6-6 is completed approximately 51 m (167 ft) deeper in the aquifer than well 299-W6-7.

Figure 2-3. Hydrographs of Tritium-Monitoring Wells Southeast of the SALDS Compared with Well 699-48-77A (Top) and Deep/Shallow Companion Wells (Bottom)

Table 2-1. Change in Water Table Elevation, March 2009 Versus March 2010

Well	March 2009 (m)	March 2010 (m)	Change from 2009 to 2010 (m)
699-48-77A[a]	135.485	135.345	-0.140
699-48-77C[a]	134.925	134.777	- 0.148
699-48-77D[a]	135.087	135.130	+0.043
699-49-79[b]	135.274	135.142	- 0.132
299-W8-1[b]	136.079	135.838	- 0.241
299-W7-12[b]	No data	No data	--
299-W7-4[b]	135.134	134.954	-0.180
299-W10-21[b]	No data	No data	--
299-W10-20[b]	No data	No data	--
299-W10-22[b]	134.284	134.110	- 0.174
299-W6-12[b]	134.329	134.052	- 0.277
299-W6-11[b]	134.002	133.692	- 0.310
299-W12-1[b]	132.406	132.184	- 0.222
699-48-71[b]	131.862	131.677	- 0.185
699-51-75[b]	133.519	133.369	- 0.150
12-month average (all wells)			**- 0.176 m**
12-month average (distal wells only)			**- 0.208 m**
12-month average, proximal SALDS wells			**- 0.082 m**

a. Proximal well.

b. Distal well.

SALDS = State-Approved Land Disposal Site

During the period from March 1997 to March 2005, the SALDS received an average of 7.98 million L (2.1 million gal) of water per month, which yielded a 0.5 to 1.0 m (1.6- to 3.3-ft)-high mound around the crib. During the period from March 2005 through March 2007, approximately 1.15 million L (304,700 gal) per month were discharged to the crib. During this time period, a groundwater mound was not apparent. The discharge rate during the period from January 2010 through August 2010 averaged 6.9 million L (1.8 million gal) per month, which is similar to the discharge rate prior to March 2005 when a comparable groundwater mound was present. It should be noted that no discharges were made in June 2010 due to thin-film dryer maintenance at the ETF (Section 1.2.3)

When present, groundwater mounding near the SALDS creates a localized downward hydraulic gradient in the aquifer. Historically, deep and shallow tritium-tracking wells 299-W6-6 and 299-W6-7 have not indicated a vertical hydraulic gradient away from the vicinity of the SALDS (see bottom plot in Figure 2-3). Well 299-W6-7 was completed at the water table, and well 299-W6-6 was completed 51 m (167 ft) deeper in the aquifer. Well 299-W6-7 is currently dry and has been dropped from the sampling schedule.

Most of the tritium-tracking wells located south of the SALDS were constructed with 6.1 m (20-ft) screens. As shown in Table 2-2, the remaining tritium-tracking wells screened in the upper aquifer will be dry before the year 2020 if the water table continues to decline at the current rate of 0.21 m/yr (0.68 ft/yr). Only wells 299-W8-1, 299-W7-3, and 299-W6-6 (which are screened deeper in the aquifer) would continue to be sampleable past the year 2016 at the current rate of decline. The head-versus-time plots for wells 299-W6-11 and 299-W6-12 (Figures 2-5 and 2-6, respectively) show the elevation of the screen bottom and generally support the calculated dry dates for the wells listed in Table 2-2.

Figures 2-7 and 2-8 show the screen elevations and projected dry dates for proximal monitoring wells 699-48-77A and 699-48-77D, respectively. Based on these plots, well 699-48-77A is expected to be dry in May 2011, and well 699-W48-77D is expected to be dry in January 2017. Due to different methods of extrapolation, these dates do not exactly match those calculated in Table 2-2, where it is assumed that the short-term rate of groundwater decline in FY 2010 will remain constant until the screen is dry. The dry dates shown graphically in Figures 2-7 and 2-8 are based on longer term rates of change, extending from the early 1990s to the present time. These wells will likely be affected by the new 200-ZP-1 OU pump-and-treat facility, which is expected to start operation in 2012. The water-level projections suggest that water levels may increase at these wells, extending the well lifetimes for 2 years or more (see Section 4.2).

2.1.2 Groundwater Flow

The arrows in Figure 2-4 denoting the interpreted groundwater flow paths indicate that effluent from the SALDS could eventually reach wells located south and east of the facility. The distance that effluent travels from the SALDS to the south before turning east is not known; however, based on both past and current model predictions, the distance is assumed to be relatively short. Interpretation of the flow paths shown in Figure 2-4 indicates that wells 699-51-75 and 699-48-71 (located 1,000 m [3,280 ft] to 2,000 m [6,560 ft] east and northeast of the SALDS) are regionally downgradient of the facility and are in reasonable locations for intercepting SALDS effluent. Increasing concentration trends of carbon tetrachloride (and nitrate at well 699-48-71), observed as part of the 200-ZP-1 OU monitoring (DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*) suggest a more northerly flow of these contaminants from the south and southwest. Increasing tritium concentration trends at well 699-48-71 are considered to be related to contaminated groundwater flowing from the south and southwest rather than from the SALDS facility.

The interpreted flow direction near the SALDS from modeling carried out in 2010 (Chapter 4 and Appendix B) represents a slightly more easterly component in the simulated migration azimuth than in previous simulations (e.g., PNNL-14898, *Results of Groundwater Modeling for Tritium Tracking at the Hanford Site 200 Area State-Approved Land Disposal Site – Fiscal Year 2004*). This difference in azimuth, amounting to only a few degrees, results in higher modeled concentrations at wells along the northern margin of the 200 West Area.

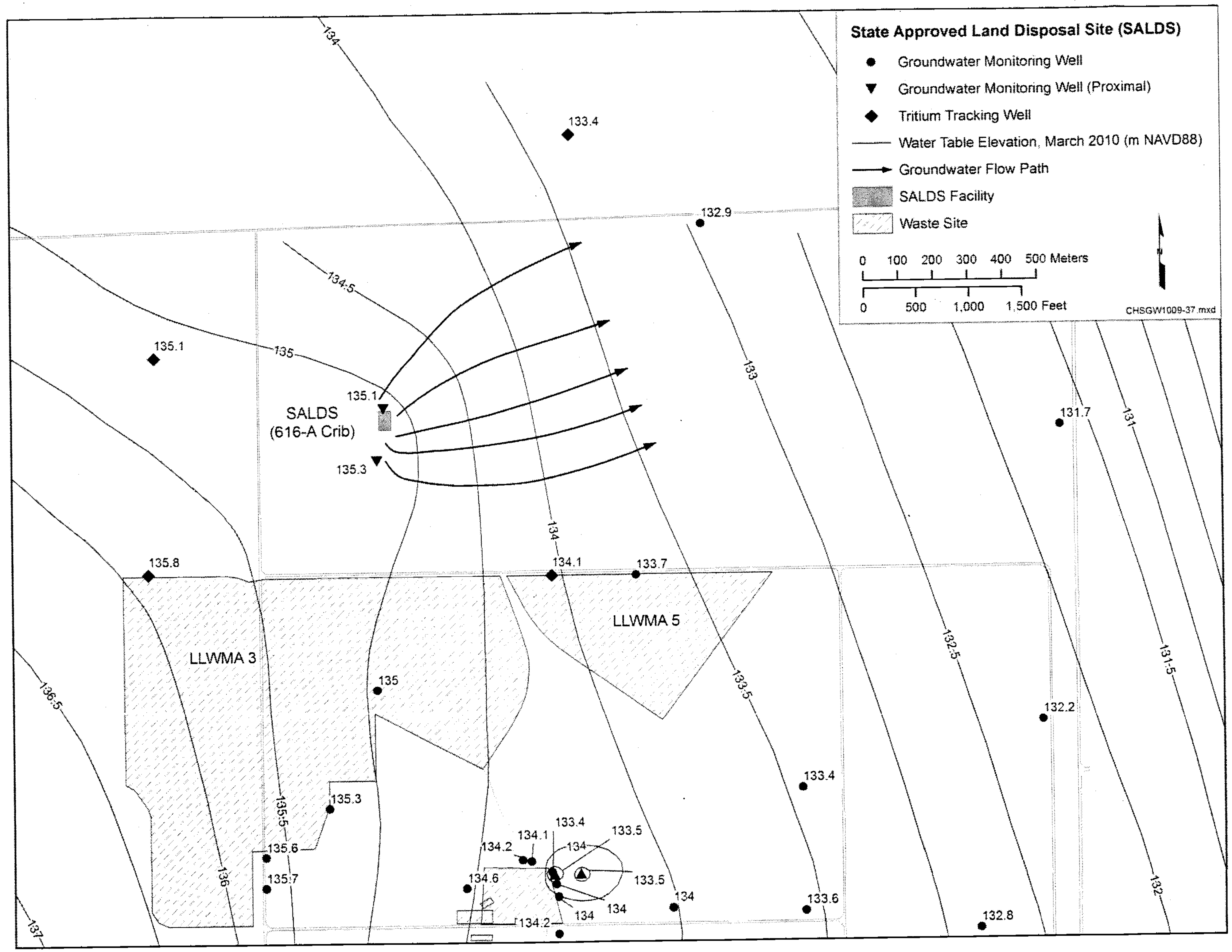


Figure 2-4. Water-Table Map and Interpreted Groundwater Flow Directions in the SALDS Area, March 2010

Table 2-2. Calculated Dry Dates for Tritium Monitoring Wells (Located Proximal to and South of the SALDS)

Well	Surface Elevation (Z in WIDL) (m)	Depth to Screen Bottom/Elevation (m)	March 2010 Water Table Elevation (m)	Saturated Screen Thickness (m)	Saturated Screen Divided by 0.32 m/yr = Years Until Well Is Dry	Calculated Dry Well Date[a]
299-W7-3	206.45	143.29 / 63.13	134.83	134.83 - 63.13 = 71.7	71.7 ÷ 0.21 = 345[b]	Not expected to go dry
299-W6-6	215.439	130.88 / 84.56	133.52	133.52 - 84.56 = 48.96	48.96 ÷ 0.21 =235[b]	Not expected to go dry
299-W6-12	211.091	78.47 / 132.75	134.05	134.05 - 132.77 = 1.28	1.28 ÷ 0.21 = 6.2	2013
299-W6-11	214.388	76.49 / 131.8	133.69	133.69 - 131.79 = 1.90	1.90 ÷ 0.21 = 9.1	2015
299-W8-1	214.29	129.54 / 78.71	135.84	135.84 - 78.71 = 57.13	57.13 ÷ 0.21 = 275[b]	Not expected to go dry
699-48-77A	205.922	70.85 / 135.07	135.35	135.35 - 135.07 = 0.42	0.42 ÷ 0.21 = 2.0[c]	2011
699-48-77C	206.585	94.49 /112.10	134.78	134.78 - 112.10 = 22.68	22.68 ÷ 0.21 = 109[c]	Not expected to go dry
699-48-77D	204.634	71.55 / 133.08	135.13	135.13 - 133.08 = 2.05	2.05 ÷ 0..21 = 9.9[c]	2017

a. Calculated dry dates are not necessarily in agreement with the dates shown in Figures 2-1 through 2-7. The calculated dates are based on the short-term rate of change over a one-year period, while the dates shown in the figures are based on long-term trends over periods that extend from 5 to 8 years.

b. Water-level decline is not expected to exceed approximately 6 m (20 ft) in the foreseeable future.

c. Regional water-level rate of decline (0.21 m/yr [0.68 ft/yr]) was used for these wells rather than the proximal well rate of decline (0.18 m/yr [0.56 ft/yr]) in order to provide a conservative estimate

WIDL = Well Information and Document Lookup

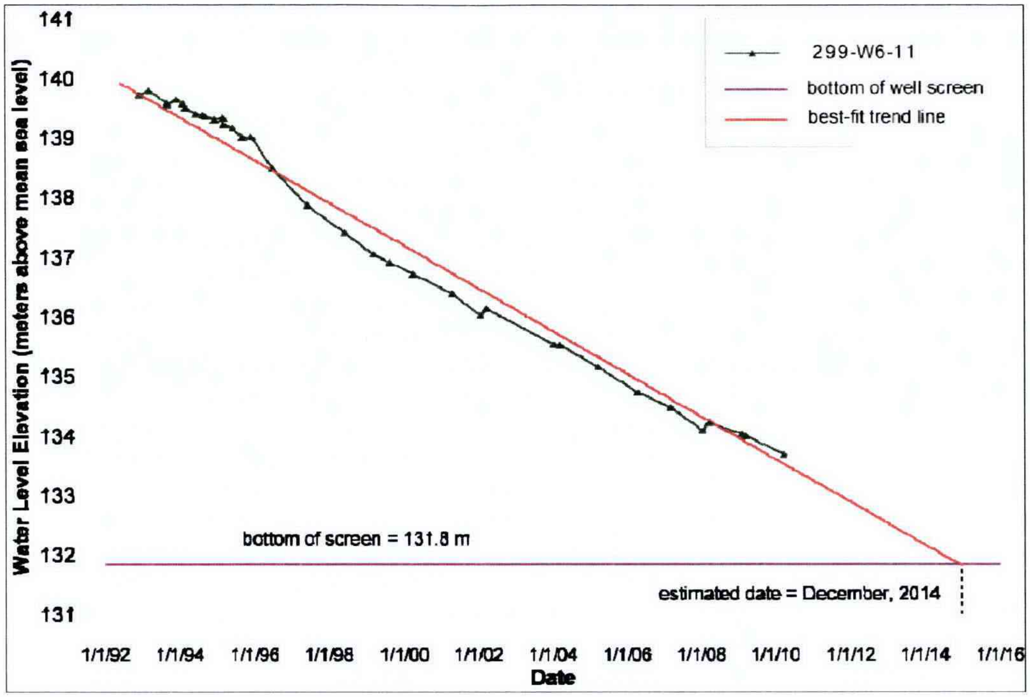


Figure 2-5. Tritium-Tracking Well 299-W6-11, Head Versus Screen

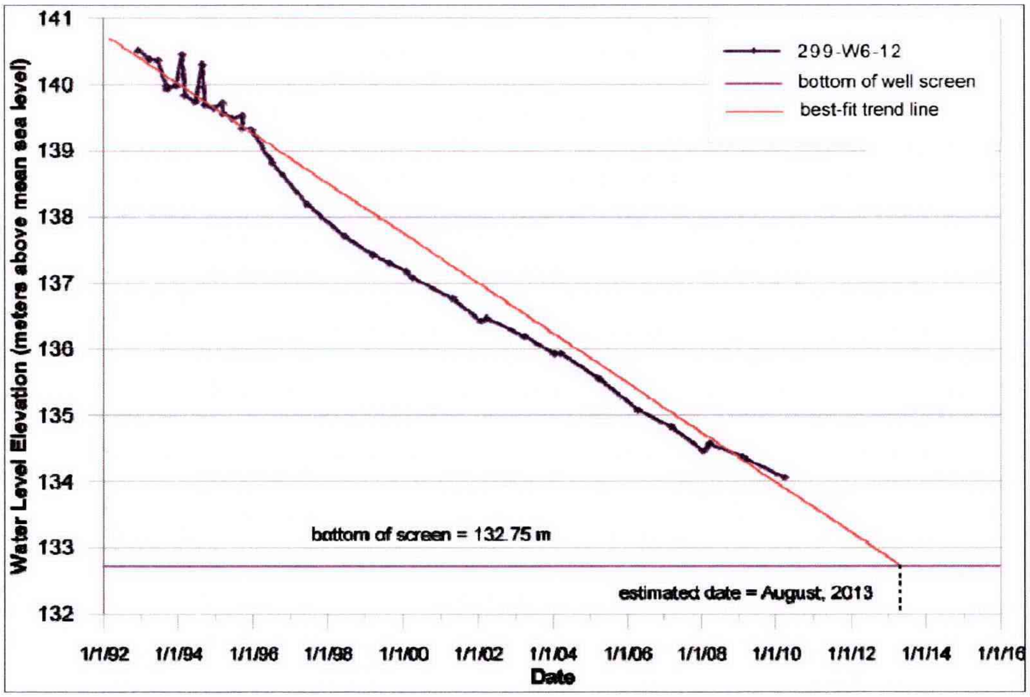


Figure 2-6. Tritium-Tracking Well 299-W6-12, Head Versus Screen

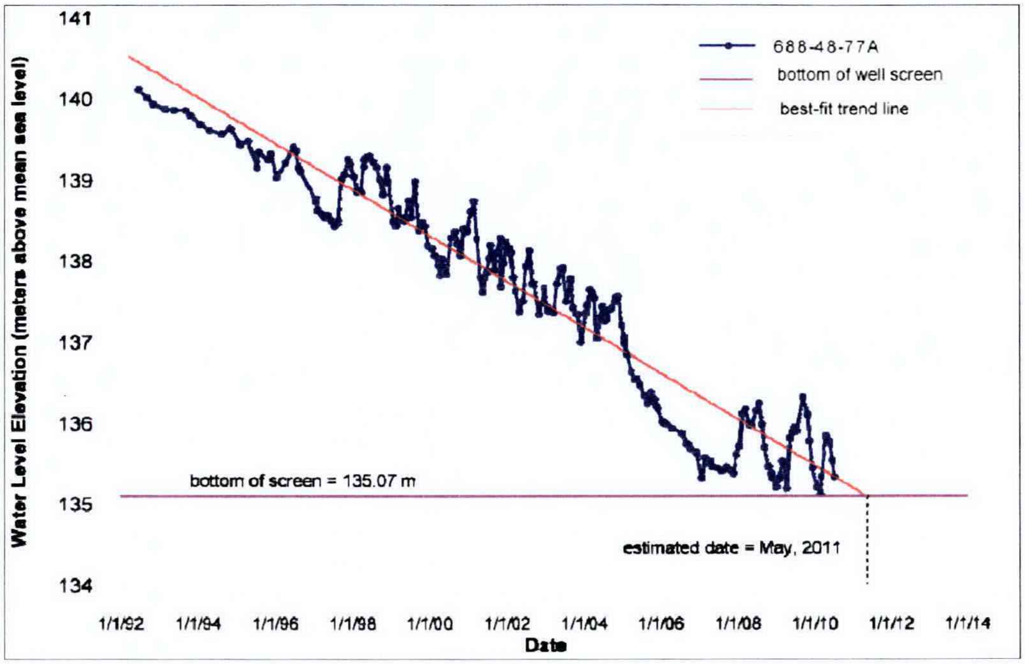


Figure 2-7. Groundwater Monitoring Well 699-48-77A, Head Versus Screen

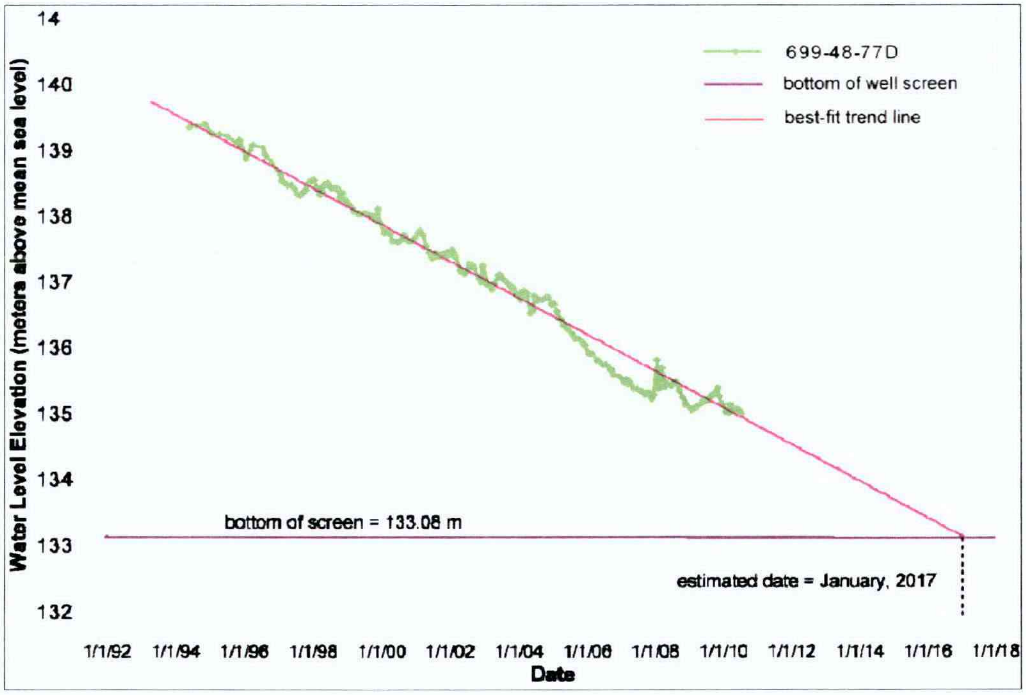


Figure 2-8. Groundwater Monitoring Well 699-48-77D, Head Versus Screen

The SALDS crib appears to be near a divide in flow between groundwater moving around the west end of Gable Butte and toward the 100-B/C Area and groundwater flowing to the east toward Gable Gap. The general decline in head, primarily resulting from discontinuation of 200 West Area operational discharges to ponds, is evident in Figures 2-1 through 2-3. An overall decline of approximately 6.0 m (19.7 ft) may be expected at the existing wells based on trend data from well 699-49-79; however, agricultural irrigation west of the Hanford Site may prevent groundwater elevations from reaching pre-Hanford levels. The discharge of effluent from ETF treating 200-UP-1 OU pump-and-treat groundwater, along with the additional discharge of effluent from ETF treating groundwater from wells near the T Tank Farm, has resulted in an expanded groundwater mound around the SALDS.

3 Results of FY 2010 Groundwater Analyses for the SALDS

Groundwater is analyzed quarterly for tritium in the SALDS proximal wells (699-48-77A, 699-48-77C, and 699-48-77D) and annually to semiannually in the tritium-tracking wells located in the vicinity of the facility (Table 3-1). Tritium results from FY 2010 are discussed in Section 3.2 and are provided in Appendix A.

Table 3-1. Sampling Schedule for SALDS Wells

Well	Sampling Frequency/Months*	Other Sampling Programs	Comments
299-W6-6	A / January	Surv-3	Deep well. FY 2010 sample date: February 2010.
299-W6-11	A / January	--	FY 2010 sample date: February 2010.
299-W6-12	A / January	Surv-3	FY 2010 sample date: February 2010.
299-W7-3	S / January, May	LLBG	Deep completion. FY 2010 sample dates: February, March, and June 2010.
299-W8-1	A / January	LLBG	FY 2010 sample dates: February and March 2010.
699-48-71	A / January	Surv-3	FY 2010 sample dates: January and February 2010.
699-48-77A	Q / October, January, April, July	Surv-3	Sampled for tritium and 15 constituents required by Permit. FY 2010 sample dates: October 2009 and February, May, and July 2010.
699-48-77C	Q / October, January, April, July	Surv-3	Sampled for tritium and 15 constituents required by Permit. Deep completion. FY 2010 sample dates: October 2009 and February, May, and July 2010.
699-48-77D	Q / October, January, April, July	Surv-3	Sampled for tritium and 15 constituents required by Permit. FY 2010 sample dates: October 2009 and February, May, and July 2010.
699-49-79	A / January	Surv-3	FY 2010 sample date: February 2010.
699-51-75	S / January, May	Surv-3	FY 2010 sample dates: February and June 2010.
699-51-75P	A / January	--	Deep piezometer in well 699-51-75. FY 2010 sample date: February 2010.

* Actual months of sampling may vary slightly due to equipment failure, winter weather, or accessibility restrictions caused by fire hazard; however, sampling frequency is generally maintained.

A = annually
FY = fiscal year
LLBG = Low-Level Burial Grounds
Q = quarterly
S = semiannually
Surv-3 = Hanford Sitewide surveillance sampling

In addition to tritium, groundwater from the proximal wells is analyzed for 17 constituents, as required by the ST-4500 Permit, Special Condition S2(B) (Ecology, 2000). Enforcement limits were set for acetone, benzene, cadmium (total), chloroform, copper (total), lead (total), mercury (total), pH, sulfate, tetrahydrofuran, and total dissolved solids. Gross alpha, gross beta, strontium-90, and tritium are not assigned enforcement limits in the Permit but are monitored and reported for informational purposes. The results for all of these parameters are reported quarterly in discharge monitoring reports. Additional parameters (e.g., alkalinity, dissolved oxygen, specific conductance, pH, temperature, turbidity, and water level) are used to determine general groundwater characteristics and to verify the quality of analytical results. Maximum concentrations for these constituents and the corresponding sample months for FY 2010 are discussed in this chapter and are listed in Table 3-2.

Table 3-2. Maximum or Range of Concentrations of Constituents in Groundwater and Corresponding Sample Month for SALDS Wells, FY 2010

Constituent (Permit Limit)	Well 699-48-77A	Well 699-48-77C	Well 699-48-77D
Acetone (160)	<1.0 (U)[a]	<1.0 (U)[a]	<1.0 (U)[a]
Benzene (5)	<1.0 (U)[a]	<1.0 (U)[a]	<1.0 (U)[a]
Cadmium, total (10)	<0.10 (U)[a]	<0.10 (U)[a]	<0.10 (U)[a]
Chloroform (6.2)	<1.0 (U)[a]	<1.0 (U)[a]	<1.0 (U)[a]
Copper, total (70)	4.2; February 2010	0.25; July 2010	0.45; May 2010
Lead, total (50)	0.11 (B); February 2010	<0.1 (U)[a]	0.17; May 2010
Mercury, total (2)	<0.05 (U)[a]	<0.05 (U)[a]	<0.05 (U)[a]
Laboratory pH, pH units[c]	7.21 to 8.08	7.30 to 7.51	7.50 to 7.68
Field pH, pH units[c] (6.5 to 8.5)	8.18 to 8.35	7.90 to 8.04	7.97 to 8.10
Sulfate (250,000)	2,370; May 2010	5,510; October 2009	17,000; October 2009
Tetrahydrofuran (100)	<2 (U)[a]	<2 (U)[a]	<2.0 (U)[a]
Total dissolved solids (500,000)	104,000; February 2010	170,000; February 2010	196,000; October 2009
Gross alpha, pCi/L[c]	2.1 (U)[a]	2.9[a] (U)	2.6; July 2010
Gross beta, pCi/L[c]	3,2; July 2010	6.4; July 2010	6.5; July 2010
Strontium-90, pCi/L[c]	1.9 (U)[a]	1.4 (U)[a]; May 2010	1.4; February 2010
Tritium, pCi/L[c]	9,600; October 2010	76,000; July 2010	180,000; October 2009, February 2010, July 2010
Alkalinity, mg/L[b, c]	46 to 54	96 to 98	110 to 130
Field conductivity, µS/cm[c]	106; February 2010	198; July 2010	263; May 2010
Dissolved oxygen, mg/L[d]	11.3; February 2010	10.5; October 2009	13.7; July 2010

Table 3-2. Maximum or Range of Concentrations of Constituents in Groundwater and Corresponding Sample Month for SALDS Wells, FY 2010

Constituent (Permit Limit)	Well 699-48-77A	Well 699-48-77C	Well 699-48-77D
Field temperature, °C[c]	21.3; July 2010	19.6; July 2010	19.1; July 2010
Turbidity, NTU[d]	18.9; February 2010	1.30; October 2009	5.11; October 2009

Notes: All concentrations in µg/L, unless otherwise noted.

a. Not detected in any sample.

b. Range of quarterly averages (pH, conductivity, dissolved oxygen, and temperature) or values (alkalinity) for FY 2010.

c. Constituent is not assigned an enforcement limit but is subject to routine monitoring and reporting.

d. Constituent is sought for evaluation of groundwater character and analytical quality and is not subject to State Waste Discharge Permit Number ST-4500 conditions (Ecology, 2000).

(B) = detected at a value less than the contract-required detection limit but greater than or equal to the instrument detection limit/method detection limit, as appropriate

FY = fiscal year

NTU = nephelometric turbidity unit

(U) = not detected; multiple minimum detection limits or lower thresholds of detection are indicated, where applicable

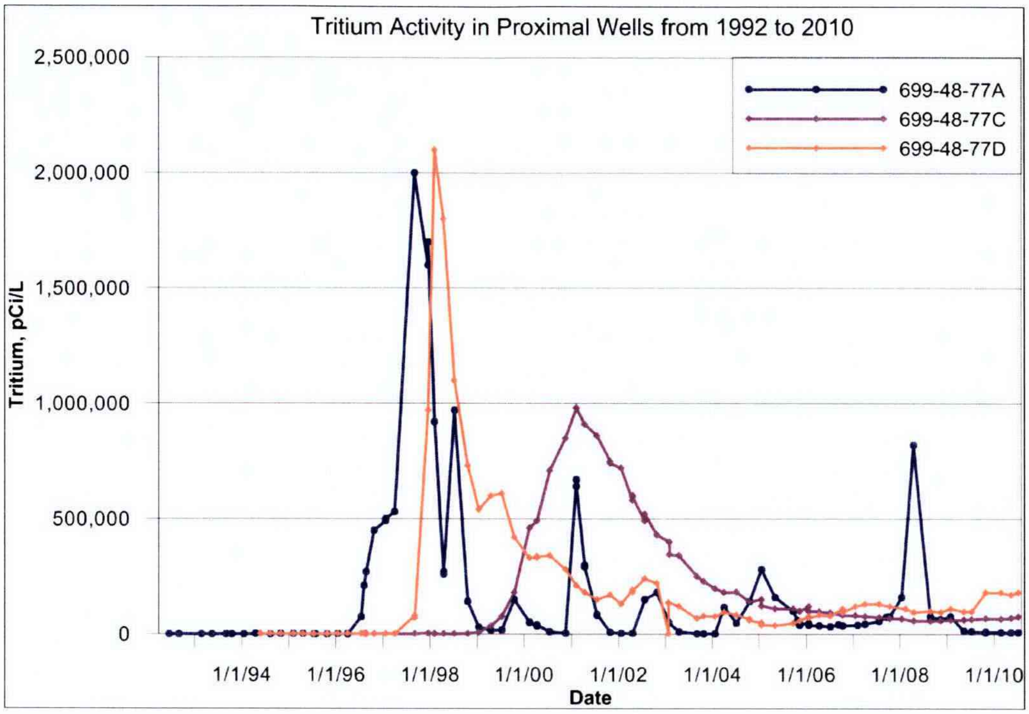
3.1 Groundwater Sampling and Analysis for FY 2010

Samples for the three proximal wells were collected in October 2009 and in February, May, and July 2010. Tritium-tracking wells are sampled annually or semiannually for tritium only. Due to generally declining water levels throughout the 200 West Area, a number of previously sampled tritium-tracking wells are currently dry and are no longer in use. Nine tritium-tracking wells were sampled in October 2009 through May 2010. Five of these wells are screened in the upper portion of the aquifer near the water table, and four wells are screened at greater depths, including one well (699-51-75P) that is a piezometer nested within well 699-51-75 but is completed 41 m (135 ft) deeper in the aquifer.

Some of the shallow-aquifer tritium-tracking wells are also sampled for a broader range of constituents for the LLBG and sitewide groundwater surveillance program. The tritium results from these programs, as well as the results collected specifically for the SALDS, are included in Appendix A.

3.2 Results of Tritium Analyses (Tritium Tracking)

Groundwater in the three proximal wells has been affected by tritium discharges since 1996. Figure 3-1 shows the tritium activity in the proximal wells since groundwater monitoring began at the SALDS. The results of tritium analyses for the tritium-tracking well network for FY 2010 are presented as trend plots in Figure 3-2, and the individual and average FY 2010 values are provided in Appendix A. Figure 3-3 shows the entire network, average tritium values at each well, and whether average concentrations increased, decreased, or remained unchanged from the previous year.



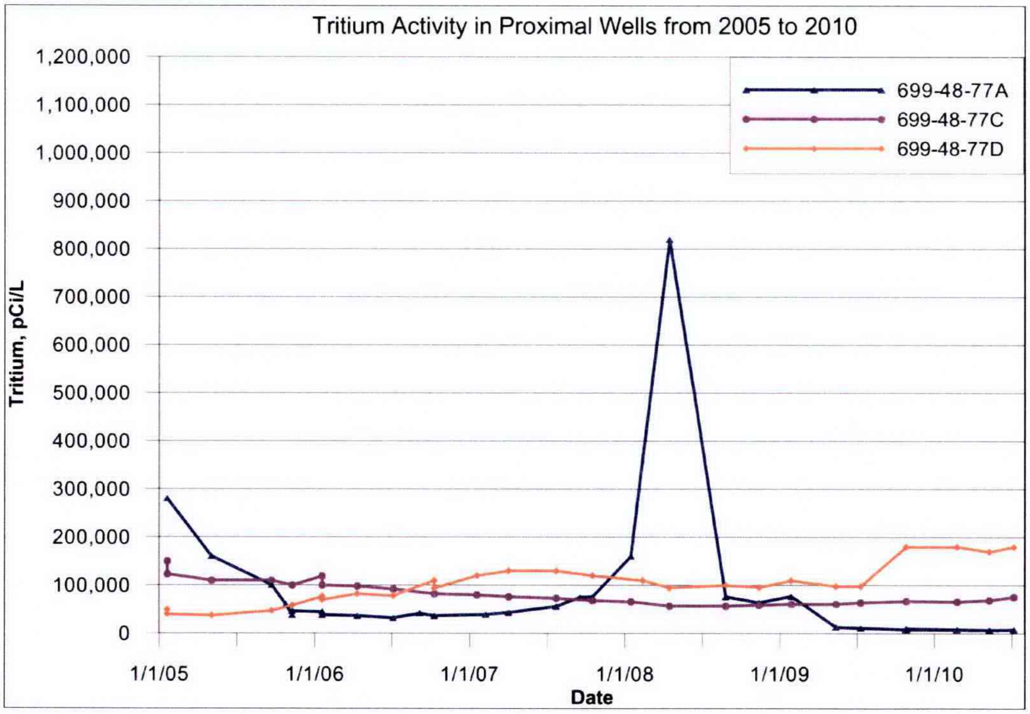
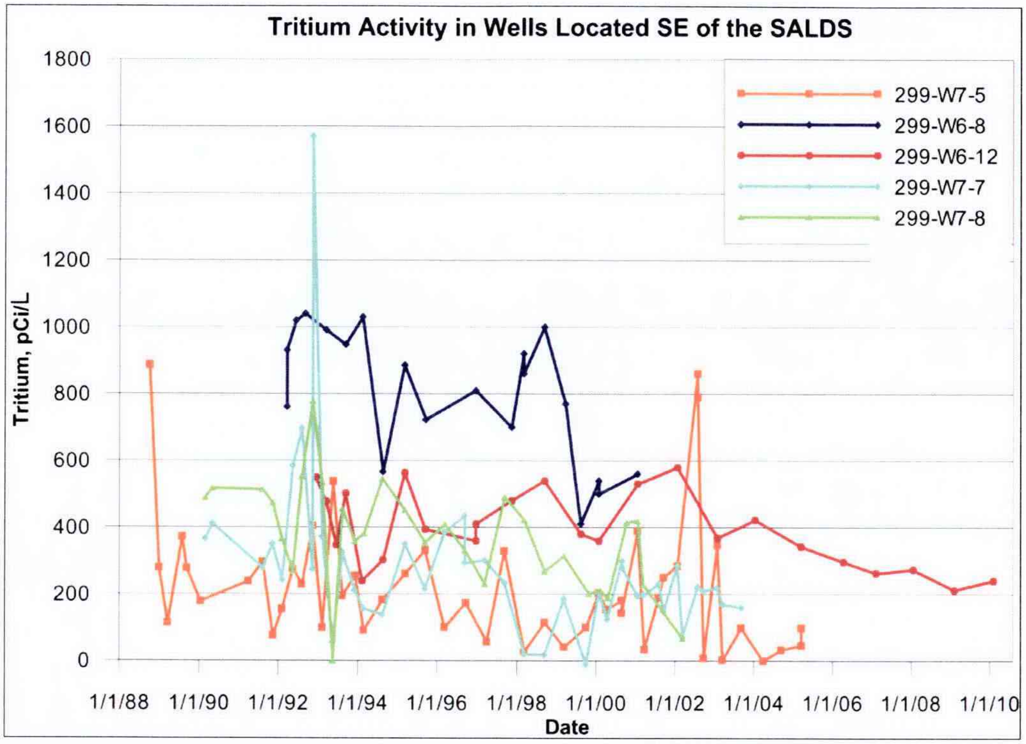


Figure 3-1. Tritium Activity Trends in SALDS Proximal Wells Through July 2010



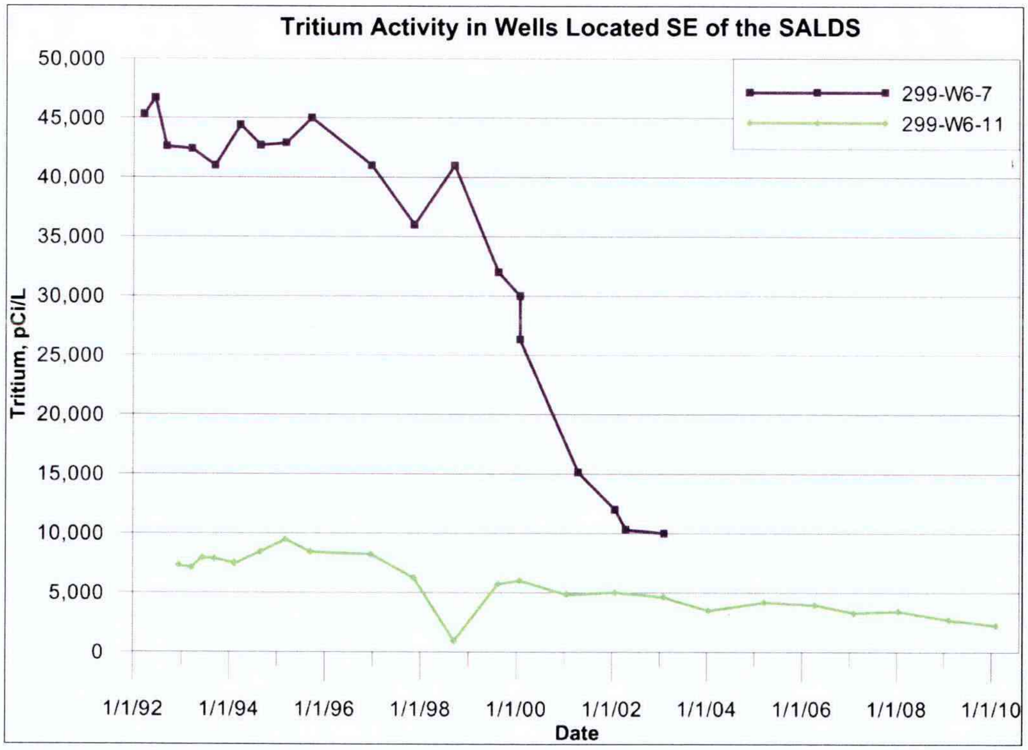


Figure 3-2. Tritium Activity Trends in Wells Southeast of the SALDS Showing Remnant Effects of the Tritium Plume from the 200 West Area

3.2.1 Proximal Monitoring Wells

Tritium activities decreased in one of three proximal monitoring wells in FY 2010 compared to FY 2009 and remained unchanged (i.e., less than 20 percent change from the previous year) in one well, and increased in one well (Figures 3-1 and 3-3). The maximum tritium concentrations in these wells and the dates that they were sampled in FY 2010 are as follows:

- Well 699-48-77A: 9,600 pCi/L (October 2009); decreased from previous year
- Well 699-48-77C: 76,000 pCi/L (July 2010); unchanged from previous year
- Well 699-48-77D: 180,000 pCi/L (October 2009, February and July 2010); increased from previous year.

3.2.1.1 Long-Term Trends

Figure 3-1 shows that peak tritium concentrations occurred in September 1997 (2,100,000 pCi/L) and February 1998 (2,100,000 pCi/L) in wells 699-48-77A and 699-48-77D, respectively. The peak concentration in well 699-48-77C (980,000 pCi/L) was delayed until February 2001, likely because this well is screened approximately 23 m (75 ft) deeper in the aquifer and it took longer for the plume front to migrate to this depth. Additionally, tritium incursions to deeper well 699-48-77C have been lower in magnitude, and cyclical variations are also absent. These differences are attributed to the deeper screen setting and the dilution and attenuation of the plume as it moves vertically through the aquifer.

Since the time of peak concentrations in these wells, the trends have been generally downward. However, changes in well 699-48-77A are irregular (Figure 3-1) with what appears to be roughly annual highs and lows of significant amplitude (sometimes two order-of-magnitude changes) from 1999 to 2005. These fluctuations likely reflect the annual campaigns of the 242-A evaporator wastewater, which is high in tritium. A more recent tritium analysis, 820,000 pCi/L in April 2008, is the highest level seen in well 688-48-77A in a decade. This was likely due to several intermittent ETF campaigns in 2006 and 2007 to treat wastewater from the K Basins project, which had tritium levels similar to that of 242-A evaporator wastewater. These intermittent campaigns restarted in FY 2010 with the ETF again treating wastewater from the K Basins project, but the effects of the discharge in August and September will not be seen until sampling during the next few years. Tritium concentrations in FY 2010 were about an order of magnitude lower than the maximum concentrations in FY 2008.

Well 699-48-77D is located nearest to the SALDS, yet the well showed a tritium incursion starting in September 1997, more than one year later than more distant well 699-48-77A. The reason for this delay is two-fold: (1) the SALDS drain field fills from the southern end of the facility furthest away from well 699-48-77D, and (2) discharged water initially moves to the south due to the southward dip of the Cold Creek unit beneath the SALDS (see Section 1.2.1). These two conditions direct the subsurface flow of effluent away from well 699-48-77D so it actually reaches the groundwater nearer to well 699-48-77A. A suggestion of a quasi-annual fluctuation is seen in the concentration trend line for well 699-48-77D (Figure 3-1), but the amplitude is significantly lower than that for well 699-48-77A.

The 6.1 m (20-ft) well screen at 699-48-77C is installed approximately 23 m (75 ft) deeper in the aquifer than at wells 699-48-77A and 699-48-77D. Peak tritium activity from the initial tritium release reached 980,000 pCi/L in February 2001, an approximate 3-year delay from peak concentrations at the other two wells. Because of the well's deeper position in the aquifer, tritium incursions from the SALDS operation showed lower peak concentrations than at the other two proximal wells. The position of the screened interval within the deeper portion of the aquifer also serves to attenuate the peaks in tritium concentration that are evident in the wells that are screened near the top of the aquifer.

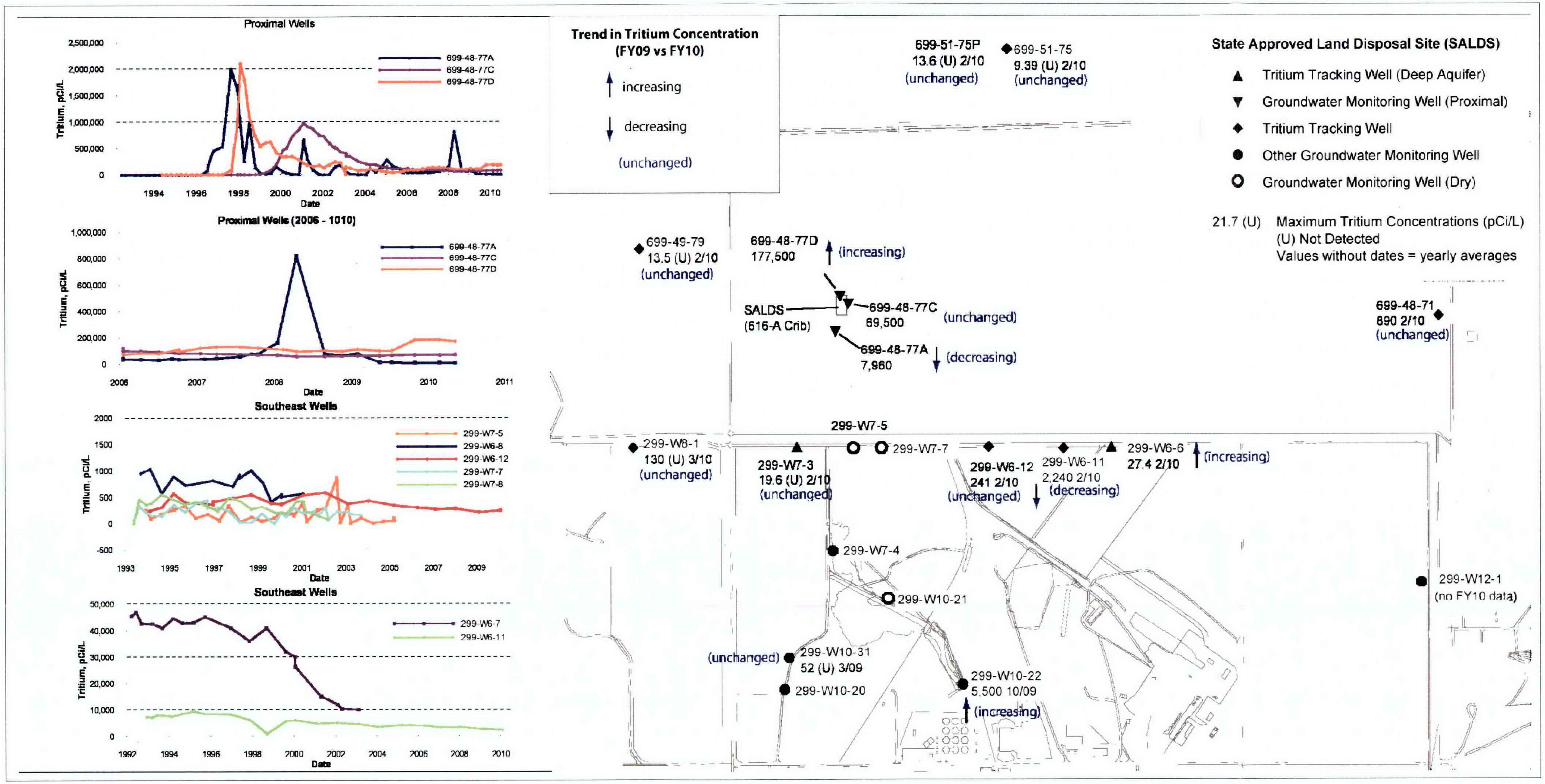


Figure 3-3. Average Tritium Activities in Groundwater for SALDS Tritium-Tracking Network for FY 2010

3.2.1.2 *Current Trends*

The current tritium trends at the three wells are mixed. Well 699-48-77C was stable during FY 2010, with little change from FY 2009 tritium concentrations. Tritium concentrations in well 699-48-77A decreased significantly between FY 2009 and FY 2010; the average tritium concentration in this well during FY 2009 was 41,250 pCi/L and the average concentration in FY 2010 was 7,960 pCi/L. This decrease is likely due to a decrease in tritium concentrations in the effluent when ETF changed from processing high tritium concentration waste (generated at the 242-A evaporator and K Basins) to low tritium concentration waste (from the 200-UP-1 OU and T Tank Farm). This trend may reverse soon as the ETF has once again started intermittent campaigns of high-tritium-concentration waste. Hydrogeologic considerations (SGW-38802) suggest that wells 699-48-77C and 699-48-77D would show somewhat delayed tritium peaks in response to the large peak seen in well 699-48-77A during FY 2008. The average tritium concentration in well 699-48-77D increased to 177,500 pCi/L in 2010 from 100,500 pCi/L, suggesting that a slug of higher concentration material discharged to the SALDS in FY 2006 and FY 2007 has reached this well.

3.2.2 Tritium Plume-Monitoring Wells

Generally, little change occurred in tritium activities in the tritium-tracking wells (Figure 3-3). The data for the tritium monitoring wells are provided in Appendix A. Wells located southeast of the SALDS have exhibited elevated activities of tritium as a result of past disposal practices in the 200 West Area. Tritium activities in well 299-W6-11 have slowly decreased over the past several years (Figure 3-2, bottom trend plot). Prior to becoming sample-dry in 2003, tritium concentrations in well 299-W6-7 had declined steadily, from more than 40,000 pCi/L in 1993 to about 10,000 pCi/L in 2002.

Well 299-W6-11, the easternmost of the remaining tritium monitoring wells, has had slowly declining tritium concentrations below 5,000 pCi/L since 2001. The maximum tritium concentrations (9,450 pCi/L) occurred in 1995, prior to the start of SALDS operations. The FY 2010 tritium concentration in well 299-W6-11 was 2,240 pCi/L, a decrease of 17 percent from 2,700 pCi/L in FY 2009.

Tritium trended slightly upward in well 299-W6-12 (Figure 3-2, top trend plot), located just west of well 299-W6-11, with a concentration of 213 pCi/L in FY 2009 and 241 pCi/L in FY 2010 (an increase of 13 percent, but within the margin of accuracy for the analyses). Previously, tritium concentrations have been nearly 600 pCi/L in this well; the source is believed to be an older tritium plume originating within the 200 West Area.

Water samples for analysis were not obtained at well 299-W7-5 in FY 2010, and the well is presumed to be dry. The FY 2005 concentration in this well was 46.3 pCi/L (Figure 3-2, top trend plot), which is near the detection limit for tritium; however, tritium in this well reached a maximum of 860 pCi/L in July 2002. Figure 3-2 shows that tritium was present prior to operation of the SALDS in 1995; therefore, tritium at this well also originated from a pre-existing plume in the 200 West Area. Numerical modeling implies that tritium from the SALDS could eventually reach this well location. Another well, 299-W8-1 (located to the west of well 299-W7-5), has occasionally detected tritium in concentrations above the detection limit. A sample collected in March 2010 returned a result of 130 pCi/L.

Distal tracking well 699-48-71, located 2 km (1.2 mi) to the east of the SALDS crib, showed a small increase in tritium concentration between FY 2009 (807 pCi/L) and FY 2010 (890 pCi/L). Tritium concentrations have been increasing at this well since about 1993. Although the well is downgradient of the SALDS crib, the distance involved suggests that the SALDS crib is not likely the primary source of tritium in groundwater at this location.

3.3 Results of Other Constituent Analyses

All 11 constituents with ST-4500 Permit limits were below the Permit limits in the proximal wells during FY 2010 (samples were collected in October 2009 and February, May, and July 2010). Acetone, benzene, cadmium, chloroform, mercury, and tetrahydrofuran were reported below detection limits in each of the three wells for each of the samples collected during FY 2010. Two target metals (i.e., lead and copper) were found at near-detection concentrations in one or more of the proximal wells. The maximum concentration of copper encountered was 4.2 µg/L at well 699-48-77A. Although copper concentrations in ETF effluent have been increasing since June 2008, the concentrations have not exceeded 1.0 µg/L. Copper has been detected in the SALDS wells since 1995, although at generally low levels. Copper levels in the proximal wells have generally been stable (at less than 8 µg/L) since analyses were first conducted in 2001.

Field pH measurements were within the pH 6.5 to 8.5 criterion in all samples collected from proximal wells during FY 2010.

Gross-alpha concentrations ranged between 2.1 and 2.9 pCi/L in the proximal wells during FY 2010, slightly higher than the background level of 1.09 pCi/L. Gross-beta values ranged between 3.2 and 6.5 pCi/L in these wells, near the background level of 5.6 pCi/L. There are no Permit limits associated with gross alpha or gross beta. Strontium-90 was below detection in all three proximal wells in FY 2010.

Several anions and metals increased in concentration after startup of the SALDS. As previously discussed, this was likely due to transport of dissolved soluble mineral species in the vadose zone during percolation of SALDS effluents (PNNL-11633, *Origin of Increased Sulfate in Groundwater at the ETF Disposal Site*; PNNL-11665, *Tritium Monitoring in Groundwater and Evaluation of Model Predictions for the Hanford Site 200 Area Effluent Treatment Facility*). The specific conductance at well 699-48-77A (a measure of total ions in solution) clearly shows a well-defined spike in the months after SALDS discharge began in December 1995 (Figure 3-4). During FY 2010, the maximum field conductivity readings ranged between 105.8 and 248 µS/cm, and total dissolved solids ranged between 105,000 and 196,000 µg/L (Figure 3-5). In general, the concentrations of total dissolved solids and specific conductance observed over the past few years appear to be slowly increasing or stable. The background levels for total dissolved solids and specific conductance (95th percentile level in both cases) are 277 mg/L and 541 mS/cm, respectively (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*).

Since well 699-48-77C is screened approximately 20 m (65.6 ft) below the water table, the vertical downward component of groundwater movement is due to mounded water. As a result, chemical contaminants in SALDS discharges are significantly delayed and subdued in the deeper well with respect to the two shallow wells. Specific conductance values gradually increased in wells 699-48-77A and 699-48-77D when the ETF ceased discharge of high volumes of effluent from the treatment of 200-UP-1 OU pump-and-treat system groundwater in March 2005. The effluent discharge, as well as additional volumes from treatment of groundwater from the T Tank Farm pump-and-treat system, was restarted in September 2007, and decreasing conductivities have been found in the two shallow aquifer wells (699-48-77A and 699-48-77D) but have not yet been noted in the deeper well (699-48-77C). Total dissolved solids trends at these three wells are highly variable and do not show clear trends.

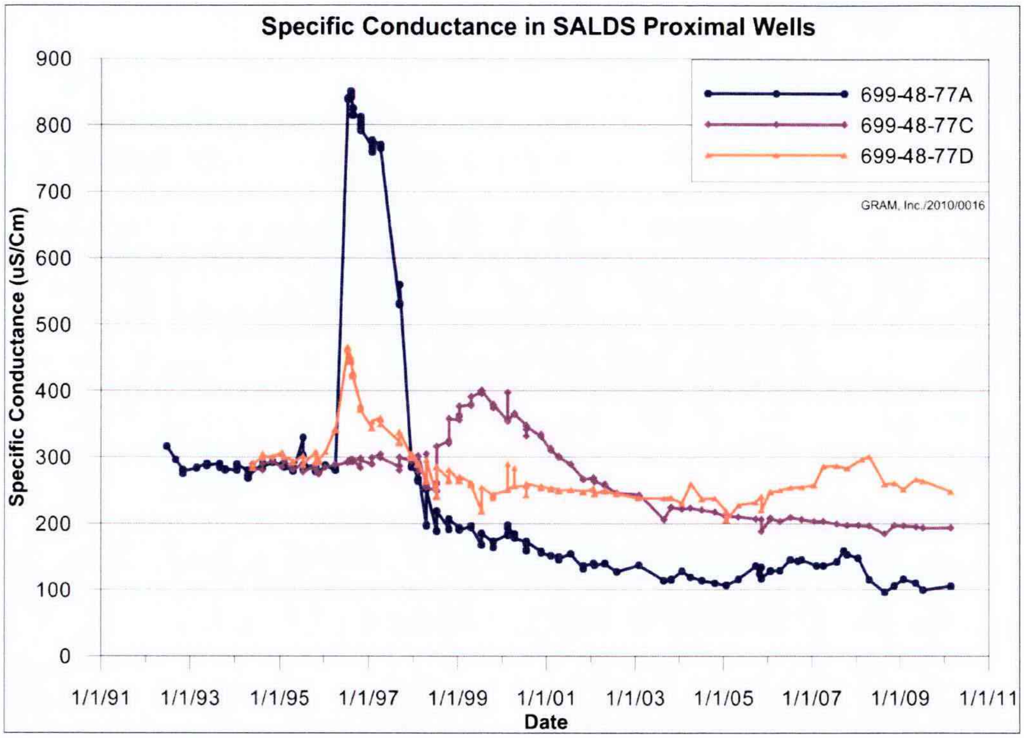


Figure 3-4. Trend Plots for Specific Conductivity in SALDS Proximal Wells

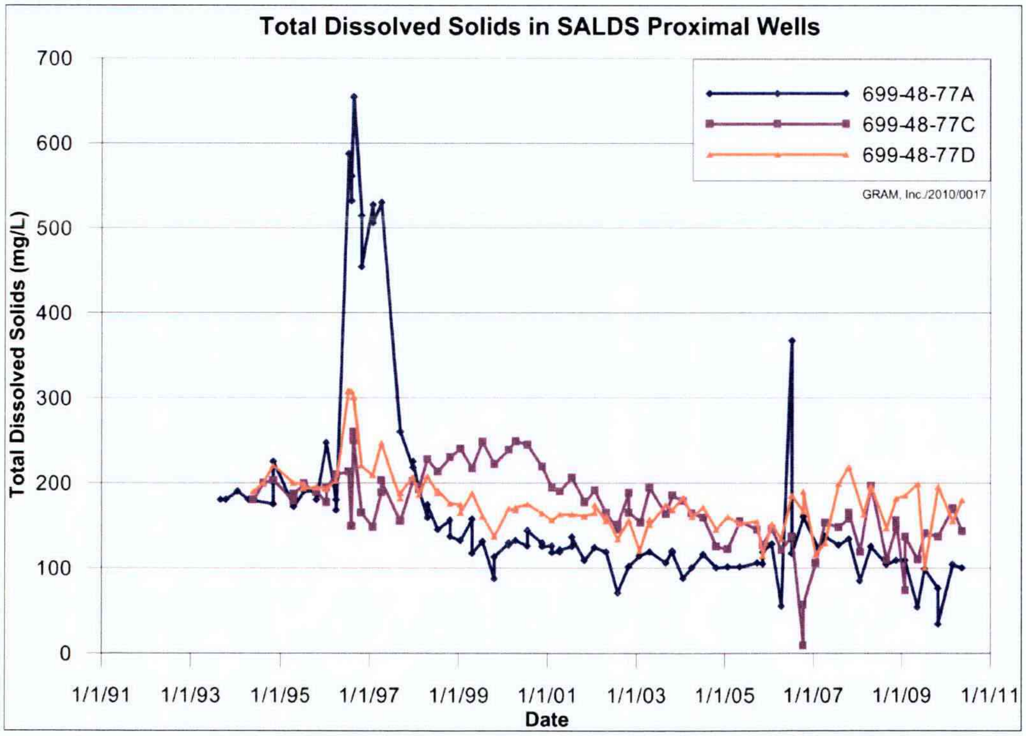
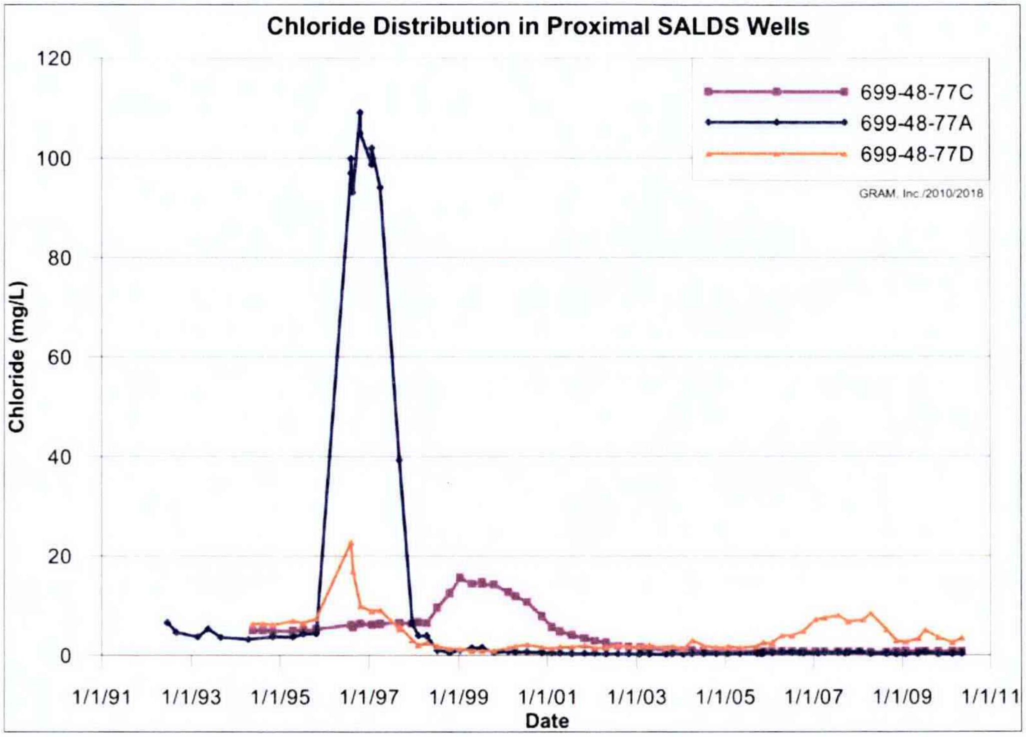


Figure 3-5. Trend Plots for Total SALDS Dissolved Solids in Proximal Wells

Similar delayed behavior is seen in Figures 3-6 and 3-7 for chloride, sulfate, calcium, and sodium in the proximal wells. These constituents are leached from the soil, so the results do not represent ETF effluent. Only sulfate analyses are required by the Permit, but all four of these constituents are useful for tracking groundwater movement. For example, the initial increase in sulfate concentration in wells 699-48-77A and 699-48-77D in December 1995 occurred within 6 months after startup of disposal to the SALDS. Sulfate concentrations did not increase in well 699-48-77C until late 1998, or 3 years after the startup of disposal. The 95th percentile background level for sulfate is 55 mg/L (DOE/RL-96-61). Since 2005, the concentrations of these four analytes have increased at well 699-48-77D, although the results from FY 2010 suggest that the trend has stabilized and may be currently showing a possible slight trend downward. At wells 699-48-77A and 699-48-77C, the concentrations are slowly declining or are stable. Similar slight downward trends are noted for FY 2010 for chloride, as well as for calcium at the shallow aquifer proximal wells. Sodium levels in all three proximal wells remained stable during FY 2010.



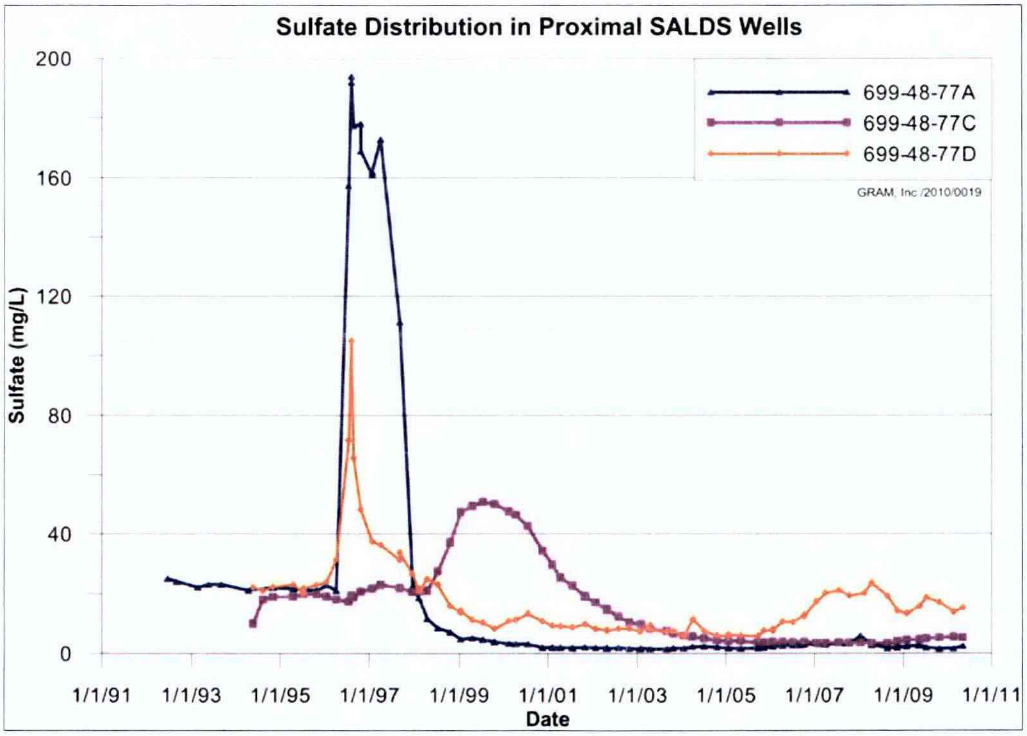
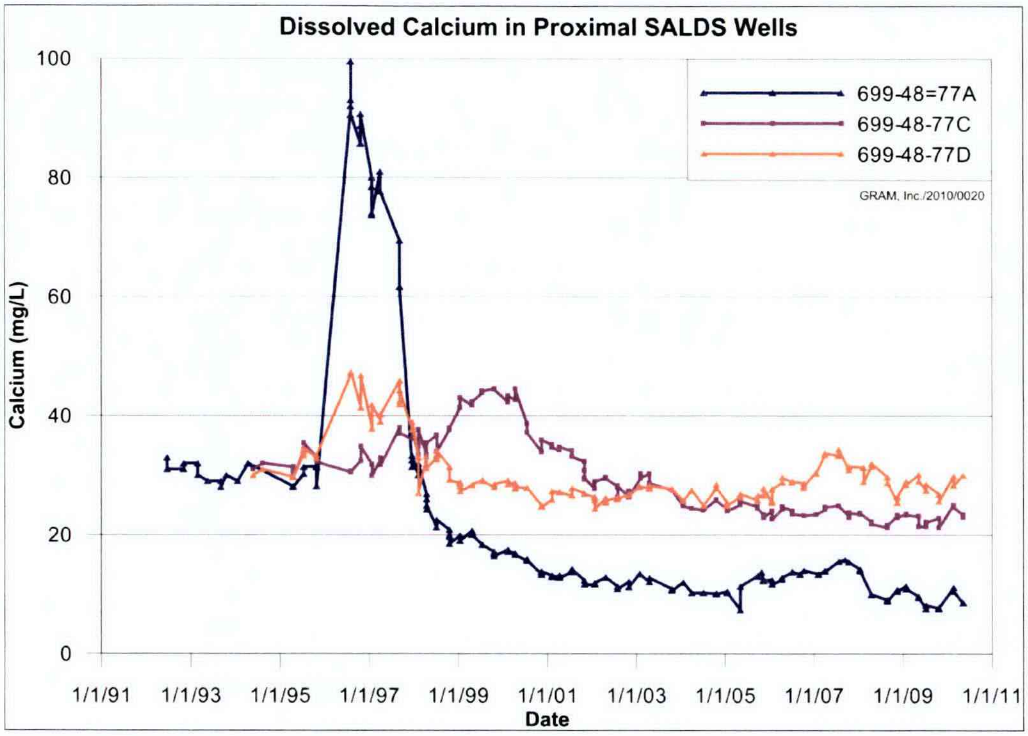


Figure 3-6. Trend Plots for Chloride (Top) and Sulfate (Bottom) in SALDS Proximal Wells



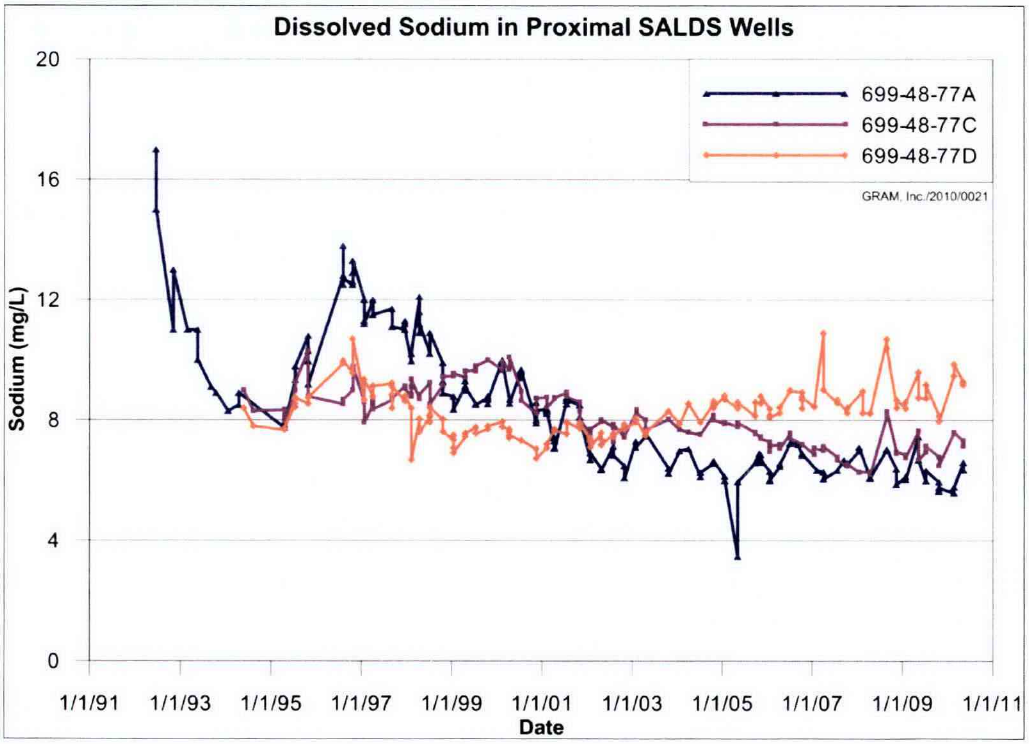


Figure 3-7. Trend Plots for Dissolved Calcium (Top) and Dissolved Sodium (Bottom) for SALDS Proximal Wells

4 Groundwater Modeling and Site Analysis

This chapter discusses groundwater modeling and site analysis for the SALDS.

4.1 Modeling Summary – Fate of Infiltrated Tritium

This section summarizes the groundwater modeling and site analysis for the SALDS, which is discussed in further detail in Appendix B. As noted in Section 1.2.2, the ST-4500 Permit (Ecology, 2000) requires an updated numerical groundwater model at least once during a Permit cycle to predict tritium movement and the distribution in the aquifer as a result of SALDS discharges. The model used to complete calculations at the SALDS presented here is the Central Plateau groundwater model, which is described in *200-West Area Pre-Conceptual Design for Final Extraction/Injection Well Network: Modeling Analyses* (DOE/RL-2008-56); DOE/RL-2009-38; and *Central Plateau Version 3 MODFLOW Model* (ECF-HANFORD-10-0371). The Central Plateau model simulates conditions from the 1940s through to the present (calibration period) and is then used to simulate likely future conditions under assumed extraction and injection rates at the 200-ZP-1 groundwater pump-and-treat remedy (SGW-47651, *Final 200-ZP-1 Pump-and-Treat Remedy: Results of FY 2010 Groundwater Flow and Contaminant Transport Simulations*). In addition to the Central Plateau model, analyses were completed using a water-level mapping technique that complements and can help verify the results obtained using the groundwater model

The analyses detailed in Appendix B used particle-tracking and reactive transport approaches to predict tritium movement and distribution through to the year 2030. The results of conservative particle-tracking analyses for the year 2030, calculated using the groundwater model and the water-level mapping technique, are shown in Figure 4-1. Particle tracking suggests that the tritium plume will migrate primarily toward the east-northeast over the next 20 years. Using either method of particle-tracking analysis, the plume is not predicted to be present 800 m (2,625 ft) downgradient in monitoring well 699-51-75, which is located to the northeast of the SALDS facility. Figure 4-2 illustrates particle tracking calculated assuming that the injected tritium is subject to dispersion (see Appendix B). Figure 4-2 suggests that some monitoring wells located along the northern margin of the 200 West Area may be located at the outer fringe of the plume by 2030.

Reactive transport modeling provides a concentration-based depiction of the distribution of tritium, rather than a path-line-based depiction as obtained from the particle tracking. The results of the reactive transport model for 2025 are shown in Figure 4-2, which presents a similar distribution to the particle-tracking analyses (results from 2025 are show for comparison with results presented in *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State-Approved Land Disposal Site Fiscal Year 2009* (SGW-42604). The modeling was completed using two assumptions for the value of the mobile porosity (0.13 and 0.18). Each of these analyses suggest that the tritium plume is not anticipated to reach tritium-tracking wells 699-51-75 (located to the northeast) or well 699-48-71 (located to the east of the SALDS facility) by 2030. However, the figures presented in Appendix B suggest that some wells along the northern margin of the 200 West Area may exhibit measurable concentrations of tritium commencing around 2015, and Figure 4-3 suggests that some of these wells may exhibit concentrations that approach the drinking water standard of 20,000 pCi/L by 2025.

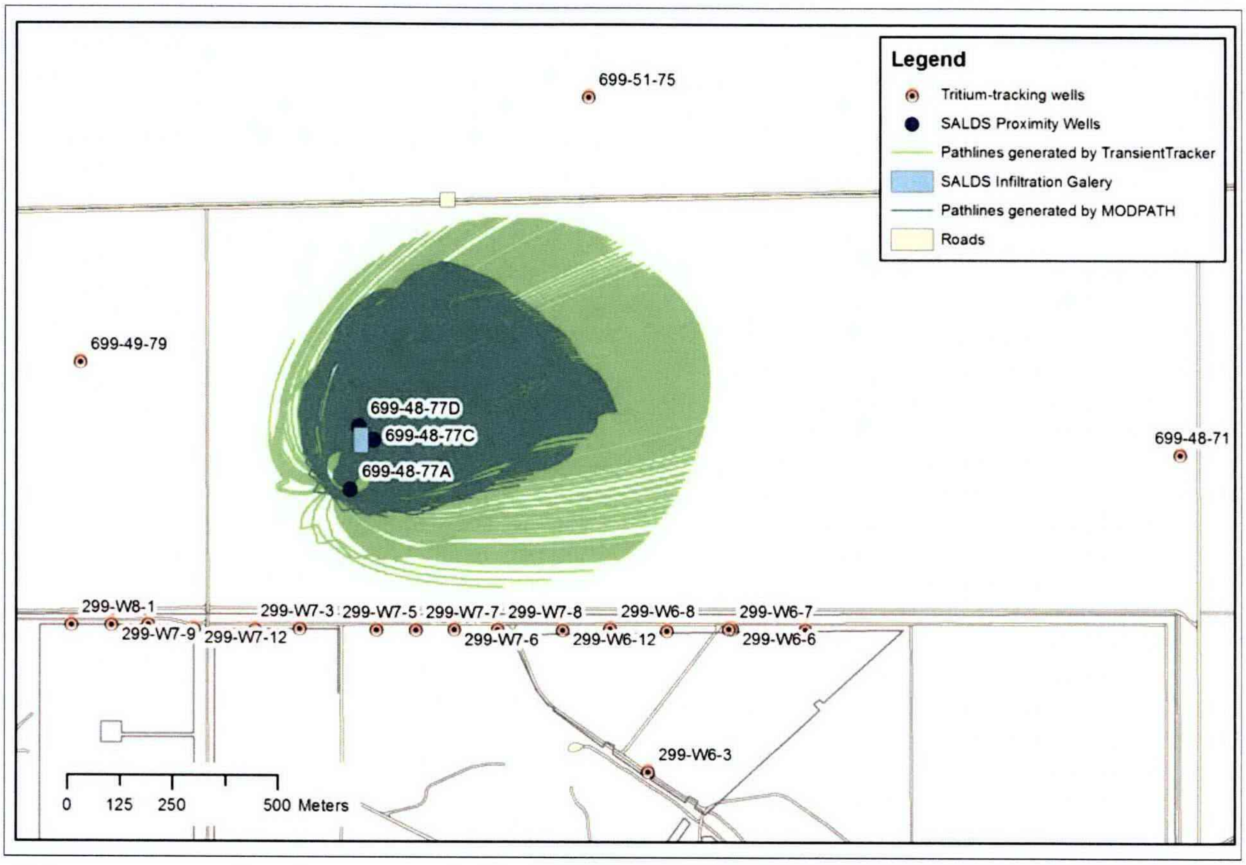


Figure 4-1. Path Lines for 2030 Calculated Using the Central Plateau Model (MODPATH) and Water-Level Mapping (Transient-Tracker)

These results differ slightly from those presented in the most recent evaluation of the SALDS facility (SGW-42604), which suggested that wells along the northern margin of the 200 West Area may be within the low-concentration marginal area (i.e., less than 5,000 pCi/L) of the plume in 2025. Comparison of the particle-tracking and reactive transport simulations presented here (and in SGW-42604) suggests that the simulated plume distributions are very similar in both reports, but that the difference in predicted concentrations at the wells along the northern margin of the 200 West Area results from a very small difference (a few degrees) in the simulated migration azimuth of the tritium. This indicates that groundwater-level monitoring in the vicinity of the SALDS is key to understanding the actual migration directions.

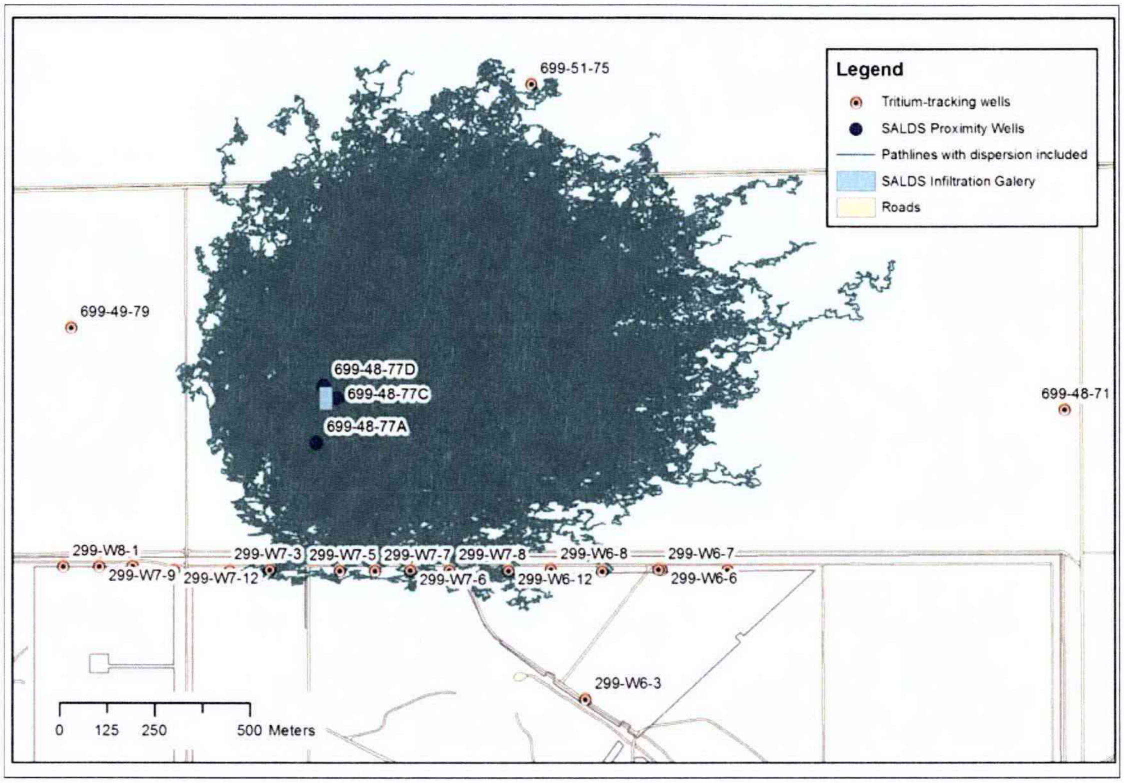


Figure 4-2. Particle Traces Produced by Transient Tracker, a Utility of the KT3D_H2O Water-Level Mapping Program, Assuming Tritium is Subject to Dispersion

4.2 Evaluation of Monitoring Well Screen Intervals

Declining water levels throughout the 200 West Area that resulted from termination of historic wastewater infiltration will over time lead to the screened intervals of a number of monitoring wells above the water table. As a result, it will not be possible to measure water levels or obtain groundwater samples from these wells. Previous evaluations of the impact of discharges at the SALDS facility, including the most recent in SGW-42604, provided estimates of the likely decline in water levels at monitoring wells in the vicinity of the SALDS based upon analyses of measured water-level trends in recent years at those wells. This approach provides a reasonable estimate of the likely decline in water levels under the assumption that significant changes in groundwater conditions are not expected. However, groundwater levels in the vicinity of the SALDS are expected to change in response to extraction and injection associated with the expanded 200-ZP-1 groundwater pump-and-treat remedy described in the *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington* [EPA et al., 2008]).

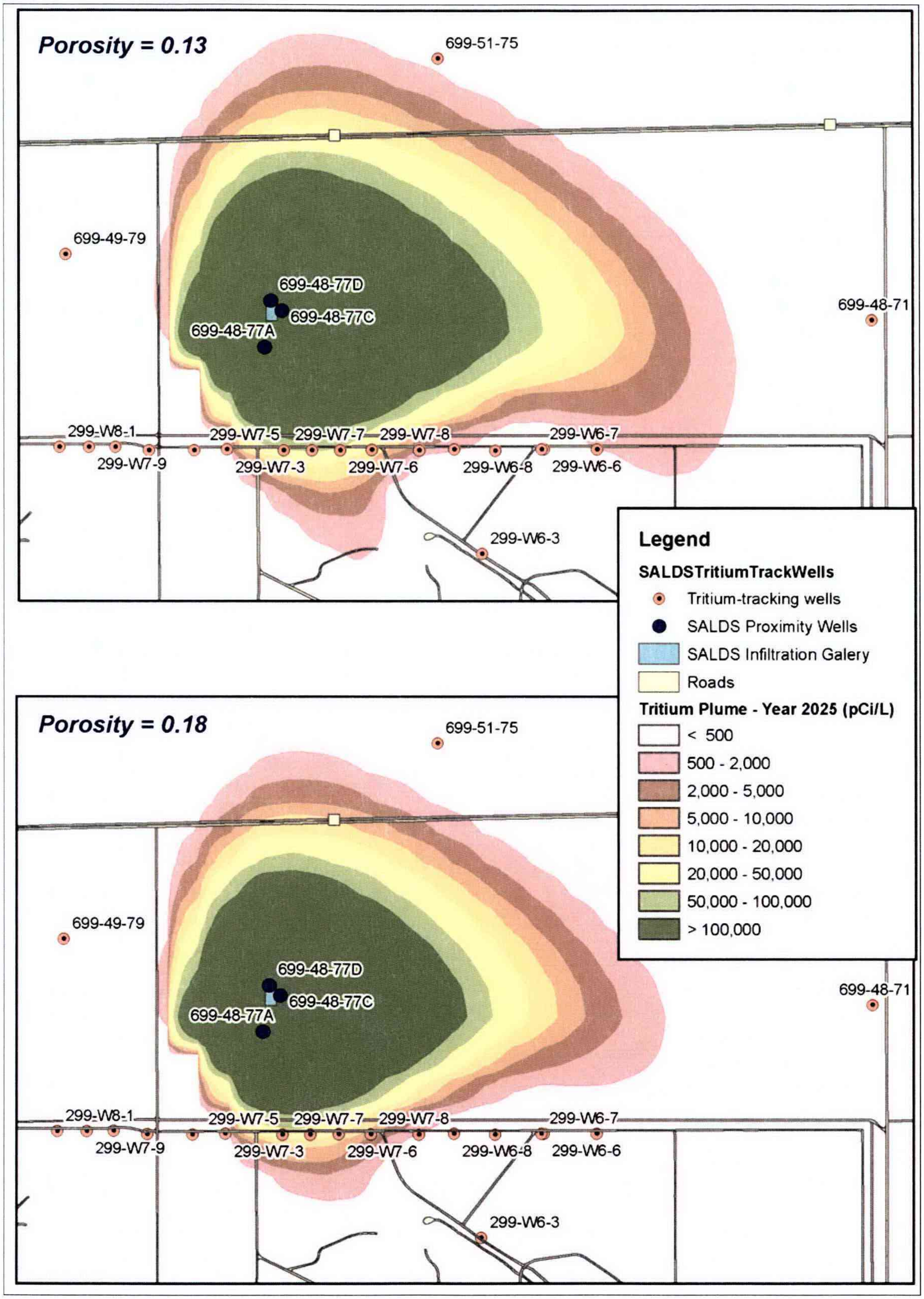


Figure 4-3. Simulated Tritium Distribution as a Result of SALDS Operation in Year 2025

Since the evaluations presented here were performed using the Central Plateau model, the evaluations incorporate the effects of projected 200-ZP-1 OU pump-and-treat operations on groundwater flow directions and rates throughout the Central Plateau model domain. The configuration of extraction and injection wells that is described in *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan* (DOE/RL-2008-78) produces simulated water levels in the vicinity of the SALDS that are impacted by both extraction and injection, with a net impact that will depend on location. Figure 4-4 depicts measured, projected, and simulated water levels at three of the principal SALDS monitoring wells (699-48-77A, 699-48-77C, and 699-48-77D), as well as the top and bottom elevation of the well screen. The measured water levels are available through June 2010. The projected water levels are calculated using a least-squares trend-line fit to the last 10 years of data record, and the simulated water levels are calculated using the Central Plateau model Version 3 (ECF-HANFORD-10-0371). Noting that to-date calibration of the Central Plateau groundwater model has focused on wider-area patterns throughout the Central Plateau, and that the three wells of interest (699-48-77A, 699-48-77C, and 699-48-77D) are close together, the following is evident from Figure B-14 in Appendix B:

- Water-level data from 2010 indicate that well 699-48-77A is nearly dry, well 699-48-77C (a deep well) has over 30 m (98 ft) of water column above the screen bottom, and well 699-48-77D has approximately 2 m (6.6 ft) of water column above the screen bottom.

- Projected water levels looking out 20 years for well 699-48-77C, calculated using either the Central Plateau model or a least-squares trend-line fit to recent data, suggest that this well screen will remain below the water table (and as a result, possible to sample) for many years.

- Water-level projections for well 699-48-77A, calculated using the Central Plateau model, incorporate the possible effects of future groundwater extraction and injection. The water-level projections suggest that water levels may increase at this well following startup of the 200-ZP-1 OU remedy, which may extend the life of this well by about 2 years or more. It is noted that water levels simulated by the current Central Plateau model correspond most closely with the measured levels at well 699-48-77A.

- Water-level projections for well 699-48-77D, calculated using a least-squares trend-line fit to recent data, suggest that this well screen will only be above the water table to late in 2012 (and as a result, not possible to sample). Water-level projections for this well calculated using the Central Plateau model, which incorporate the possible effects of future groundwater extraction and injection, suggest that water levels may increase at this well following startup of the 200-ZP-1 OU remedy, which may extend the life of this well by about 2 years or more.

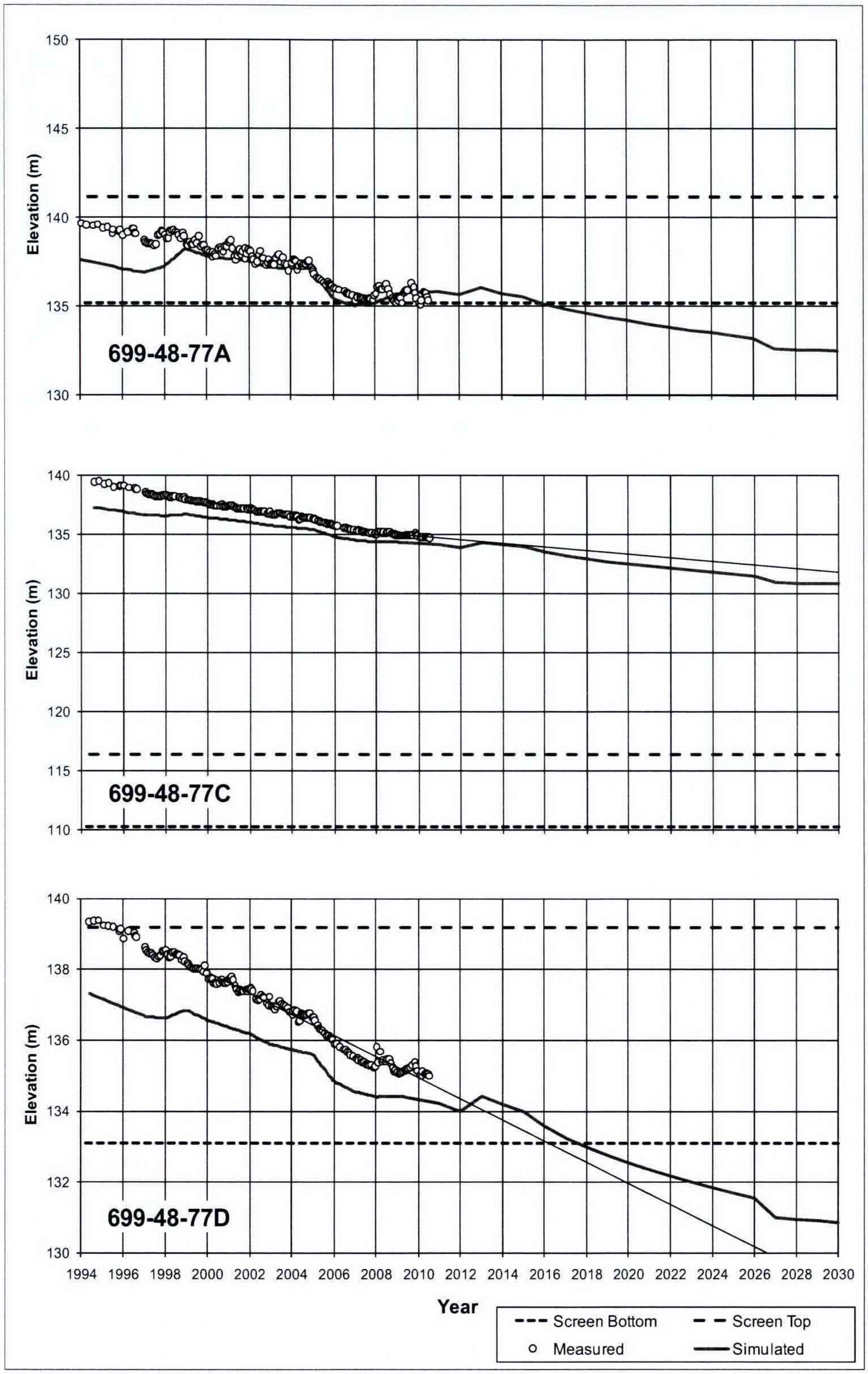


Figure 4-4. Measured, Projected, and Simulated Water Levels at Wells 699-48-77A, 699-48-77C, and 699-48-77D

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Appendix A

State-Approved Land Disposal Site Tritium Results for Fiscal Year 2010

A State-Approved Land Disposal Site Tritium Results for Fiscal Year 2010

Table A-1. SALDS Tritium Results, FY 2010

Well	Date Sampled	2010 Tritium Analyses (pCi/L)	Lab. Qualifier	2009 Tritium Max. (pCi/L)	2010 Tritium Max. (pCi/L)	Trend
299-W6-11	02/02/10	2,700	--	2,700	2,240	Unchanged
299-W6-12	02/02/10	241	--	263	241	Unchanged
299-W6-6	02/02/10	27.4	--	U[a]	27.4	--[b]
299-W7-3	02/02/10	19.6	U	U[a]	U[a]	--[b]
	03/28/10	13	U			
	06/01/10	-16.4	U			
299-W8-1	02/02/10	23.8	--	820	23.8	Decreasing
	03/28/10	-16	U			
	03/28/10	130	U			
699-48-71	01/07/10	810	--	898	890	Unchanged
	02/02/10	890	--			
699-48-77A	10/26/09	7,800	--	77,000	9,600	Decreasing
	10/26/09	9,600	--			
	02/23/10	8,000	--			
	05/10/10	6,900	--			
	07/07/10	7,500	--			
699-48-77C	10/26/09	67,000	--	64,000	76,000	Unchanged
	02/23/10	66,000	--			
	05/10/10	69,000	--			
	07/07/10	76,000	--			

Table A-1. SALDS Tritium Results, FY 2010

Well	Date Sampled	2010 Tritium Analyses (pCi/L)	Lab. Qualifier	2009 Tritium Max. (pCi/L)	2010 Tritium Max. (pCi/L)	Trend
699-48-77D	10/26/09	180,000	--	110,000	180,000	Increasing
	02/23/10	180,000	--			
	05/10/10	170,000	--			
	07/07/10	180,000	--			
699-49-79	02/02/10	13.5	U	U[a]	U[a]	--[b]
	02/02/10	4.47	U			
699-51-75	02/03/10	9.39	U	U[a]	U[a]	--[b]
	06/21/10	-42.4	U			
699-51-75P	02/03/10	13.6	U	U[a]	U[a]	--[b]

Notes: Increase = 20% higher maximum concentration in FY 2010 than in FY 2009, decrease = 20% lower concentration in FY 2010 than in FY 2009, unchanged = FY 2010 concentration within 20% of FY 2009 value.

a. Less than detection.

b. Trend not applicable due to less than detection values .

FY = fiscal year

Appendix B

Groundwater Modeling and Site Analysis

Contents

Figures

B Groundwater Modeling and Site Analysis

This appendix discusses the groundwater modeling and site analysis for the State-Approved Land Disposal Site (SALDS). The model used to complete calculations at the SALDS facility is the Central Plateau groundwater model, which was originally the 200-ZP-1 Groundwater Operable Unit (OU) groundwater model described in *200-West Area Pre-Conceptual Design for Final Extraction/Injection Well Network: Modeling Analyses* (DOE/RL-2008-56), as updated during 2009 and 2010 (DOE/RL-2009-38, *Description of Modeling Analyses in Support of the 200-ZP-1 Remedial Design/Remedial Action Work Plan*; ECF-HANFORD-10-0371, *Central Plateau Version 3 MODFLOW Model*). As described in DOE/RL-2009-38 and ECF-HANFORD-10-0371, the Central Plateau model simulates conditions from the 1940s through to the present (calibration period) and is then used to simulate likely future conditions under assumed extraction and injection rates at the 200-ZP-1 groundwater pump-and-treat remedy (SGW-47651, *Final 200-ZP-1 Pump-and-Treat Remedy: Results of FY 2010 Groundwater Flow and Contaminant Transport Simulations*).

Groundwater pump-and-treat operations within the 200-ZP-1 OU are expected to overlap in time with SALDS operations and are expected to impact groundwater flow directions and rates in the vicinity of the SALDS. Since the evaluations presented here were performed using the Central Plateau model, the evaluations incorporate the effects of projected 200-ZP-1 pump-and-treat operations ("Base Case 1," as presented in SGW-47651) on groundwater flow directions and rates throughout the Central Plateau model domain. Over time, it is expected that additional information will become available on the actual operations at the 200-ZP-1 OU, on the hydrostratigraphy, and on the actual (measured) response of the groundwater system to pumping at the 200-ZP-1 OU. This information will be incorporated into future revisions of the Central Plateau model, which is expected to improve the current conceptual model and parameter distributions for this site, resulting in higher confidence in model projections (NUREG/CR-6805, *Comprehensive Strategy of Hydrogeologic Modeling and Uncertainty Analysis for Nuclear Facilities and Sites*).

B1 Background

Numerical simulations of groundwater flow and contaminant transport have been conducted for the SALDS since the planning stages of the facility began in 1991. Discussion of these groundwater models and of two relevant vadose zone flow models is presented in *Tritium Monitoring in Groundwater and Evaluation of Model Predictions for the Hanford Site 200 Area Effluent Treatment Facility* (PNNL-11665). Early two-dimensional models (e.g., WHC-MR-0276, *Groundwater Mounding and Plume Migration Analyses for Candidate Soil Column Disposal Sites, Hanford Site, Washington*) used conservatively high values for SALDS operations and assumed steady-state conditions. Some of these conservative models predicted that tritium would reach the Columbia River in +100 years at concentrations near the drinking water standard of 20,000 pCi/L. Later models, such as presented in *Hanford Sitewide Groundwater Remediation Strategy – Groundwater Contaminant Predictions* (BHI-00469), considered three-dimensional flow and transport, incorporating realistic operating scenarios for the SALDS, tritium decay, and transient flow conditions. These models suggested that the tritium plume generated by the SALDS would remain within about 2 km (1.2 mi) of the facility until the plume decayed.

Until recently, the Soil and Groundwater Remediation Project used a Hanford Sitewide groundwater flow and contaminant transport model to predict future conditions of the unconfined aquifer due to cessation of

Hanford Site operations (e.g., determining which monitoring wells will become dry due to declining water levels). The sitewide groundwater flow and transport model was also used to assess the potential for contaminants to migrate from the Hanford Site via the groundwater pathway and to address site-specific contaminant issues (e.g., SALDS). Developed by Pacific Northwest National Laboratory, that model is based on the Coupled Fluid, Energy, and Solute Transport (CFEST) code (*Coupled Fluid, Energy, and Solute Transport [CFEST] Model: Formulation and User's Manual* [Gupta et al., 1987]). Using the CFEST model, transient simulations were performed for the period of 1980 through 2100, with the SALDS assumed to receive tritium from 1996 through 2025, as well as effluent with no tritium through the year 2034. Model results were illustrated as hydraulic head distributions, lateral tritium plume extents (plumes), and vertical distribution of tritium in the vicinity of the SALDS. In 2004, *Results of Groundwater Modeling for Tritium Tracking at the Hanford Site 200 Area State-Approved Land Disposal Site – 2004* (PNNL-14898) presented the results of numerical simulations that were performed using a sitewide CFEST model that had been updated from the model used in PNNL-11665.

In the following discussion, the likely migration of tritium is evaluated using three complementary methods of analyses, based on water-level mapping and groundwater modeling, to build confidence in the results obtained. These analysis methods are listed below, and their applications are described in the following sections:

- Water-level mapping and particle tracking: This analysis provides a preliminary understanding of likely groundwater flow directions and tritium migration rates in the vicinity of the SALDS to help validate the reasonableness of the groundwater modeling results.
- Groundwater flow modeling and particle tracking: This analysis provides estimates of likely groundwater flow directions and tritium migration rates in the vicinity of the SALDS for comparison with the estimates obtained using the water-level mapping approach.
- Groundwater flow and contaminant transport modeling: This analysis provides estimates of tritium migration rates and the likely future distribution of tritium concentrations in groundwater in the vicinity of the SALDS discharge.

The site conceptual model that underpins these analyses is based primarily upon PNNL-14898 and DOE/RL-2008-56. Model hydrostratigraphic layering and contact elevations are derived from *Groundwater Data Package for Hanford Assessments* (PNNL-14753). Hydrologic and geochemical parameters are derived from the *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit* (DOE/RL-2007-28). These documents constitute the principal basis for the conceptual and parametric model components. In addition to these documents, a more recent report evaluating groundwater at the SALDS (SGW-42604, *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State-Approved Land Disposal Site Fiscal Year 2009*) used the three methods described above in addition to a superposition analysis to identify the approximate location that the SALDS discharge reaches the unconfined aquifer water table. This superposition analysis is not repeated in detail here but is summarized below to provide a basis for the water-level mapping and groundwater modeling analyses that follow.

B2 Analyses of Groundwater Flow Using Superposition

Evidence suggests that the stratified geologic sequence encountered within the vadose zone beneath the SALDS facility results in SALDS discharge water intercepting the water table at a location laterally displaced from the facility (PNNL-13121, *Groundwater Monitoring and Tritium-Tracking Plan for the 200 Area State-Approved Land Disposal Site*). Groundwater chemical analyses indicate that well 699-48-77A (the southernmost but upgradient proximal well furthest from the SALDS) responds to discharges several months earlier than well 699-48-77D and about 2 years earlier than well 699-48-77C. The interpretation of this pattern of well response is that the carbonate-cemented horizons of the Cold Creek unit occur within the vadose zone below the base of the SALDS drain field and lead to a lateral displacement of the discharged wastewater.

To investigate the approximate location where the SALDS water discharges to the water table (as well as the location from which particles should be tracked, and where tritium-laden wastewater should be loaded in the transport model), an analysis was completed using superposition. This analysis used a program that calculates transient potentiometric head surfaces by superimposing drawdown and/or mounding calculated using the Theis equation on a uniform background gradient ("The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage" [Theis, 1935]; DOE/RL-2007-28). The analysis is detailed in the fiscal year 2009 SALDS report (SGW-42604). The analysis included a calibration of the inputs to the program through comparison of measured water levels with those computed using the superposition approach. In this instance, the SALDS discharge times, rates, and location; aquifer transmissivity and storage; and background hydraulic gradient were considered fixed. The program was then used to calculate changes in water levels at the location of the three SALDS monitoring wells exhibiting the strongest water-level response to SALDS discharges (699-48-77A, 699-48-77D, and 699-48-77C). The easting and northing coordinates of the location that the discharge water reaches the water table were estimated. The results are detailed in Appendix B of SGW-42604: the estimated "best-fit" coordinates of the discharge location are (in North American Datum [NAD] 1983 State Plane, Washington South FIPS 4062) easting at 566395.40 m and northing at 137979.33 m. These coordinates were used in the following analyses as the assumed location of discharge to the water table. The coordinates were also used as the source of particles in particle-tracking analyses and the source of contaminants in the contaminant transport analyses.

B3 Water-Level Mapping and Particle Tracking

Water-level mapping was used with particle tracking to provide an understanding of likely groundwater flow directions and tritium migration rates, and also to help validate the reasonableness of the results obtained using the groundwater model. The mapping and particle-tracking analysis were performed using the program KT3D_H2O Version 3 ("KT3D_H2O: A Program for Kriging Water-Level Data Using Hydrologic Drift Terms" [Karanovic et al., 2009]), which is a graphical user interface that combines various programs to generate gridded maps of water-level elevations and compute particle paths.

Water-level maps were prepared using a technique that combines universal kriging (i.e., kriging with a trend) with trend terms that describe the change in water levels (drawdown or mounding) in response to point sinks or sources of water (SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*). When using this approach, the spatially varying mean or underlying trend in the water levels is calculated as a summation of a background gradient with the effects of wastewater discharge at the easting and northing coordinates corresponding to the estimated location at which the discharged water reaches the unconfined aquifer (described above). Using universal kriging serves the same purpose as the de-trending applied in the groundwater superposition analysis described above and in SGW-42604.

Water-level maps were prepared using 15 sets of average yearly water levels, collected from 1995 through 2009, plus one set of average water levels from January through July 2010. For each of these averaged water-level data sets, a point-source trend term was included in the kriging at the location of the estimated SALDS arrival at the water table, with a magnitude equivalent to the annual average SALDS discharge rate. Together, the ensemble of maps calculated from 1995 through 2010 describe approximate groundwater water levels and flow directions and can be considered sequential annual "snapshots" of the actual transient conditions that are encountered in the field. Particle tracking on these surfaces, reflecting changing groundwater conditions over time, can illustrate approximate migration directions and rates for water and dissolved contaminants discharged to the water table. To complete the particle tracking, the movement of a parcel of water and dissolved contaminants are tracked by calculating the gradient of the water-level surface, and assuming a representative hydraulic conductivity and effective (mobile) porosity for the aquifer. Particle tracking was performed using a program that implements the Runge-Kutta (RK) integration technique (*Numerical Recipes in Fortran-90* [Press et al., 1996]) to calculate particle paths within the KT3D_H2O graphical user interface (DOE/RL-2007-28; Karanovic et al., 2009).

Figure B-1 illustrates the particle paths calculated from the assumed SALDS discharge location described above. Each particle was released in 1995, and the migration of each particle was calculated for 365 days on each of the calculated water-level surfaces from 1995 through the end of 2009, and for 21 years (2010 through 2030) on the map representing 2010 conditions. Thus, using the water-level mapping approach, conditions existing today are assumed to exist until 2030. The particle paths presented in Figure B-1 were calculated assuming advective transport only, while Figure B-2 presents the particle paths calculated assuming a longitudinal dispersion of 30 m (98.4 ft) and transverse dispersion of 5 m (16.4 ft), calculated using the "random-walk" method for representing Fickian dispersion (*A "Random-Walk" Solute Transport Model for Selected Groundwater Quality Evaluations* [Prickett et al., 1981]; *Applied Contaminant Transport Modeling, 2nd Edition* [Zheng and Bennett, 2002]). The results provide approximate depictions of the likely direction and distance traveled by the tritium discharged at the SALDS.

B4 Groundwater Modeling

The use of the groundwater model to provide an additional estimate of the direction and extent of tritium migration is described in the following sections.

B4.1 Background

As described above, simulations of groundwater flow and tritium transport were previously completed using a sitewide model. Recently, a groundwater flow and contaminant transport model was developed to design the 200-ZP-1 OU groundwater pump-and-treat remedy. Details of the extents, discretization, and parameterization of this model can be found in several reports prepared for the 200-ZP-1 OU (e.g., DOE/RL-2008-56, DOE/RL-2009-38, and SGW-47651), as well as a calculation brief that documents revisions to and calibration of this Central Plateau model (ECF-HANFORD-10-0371).

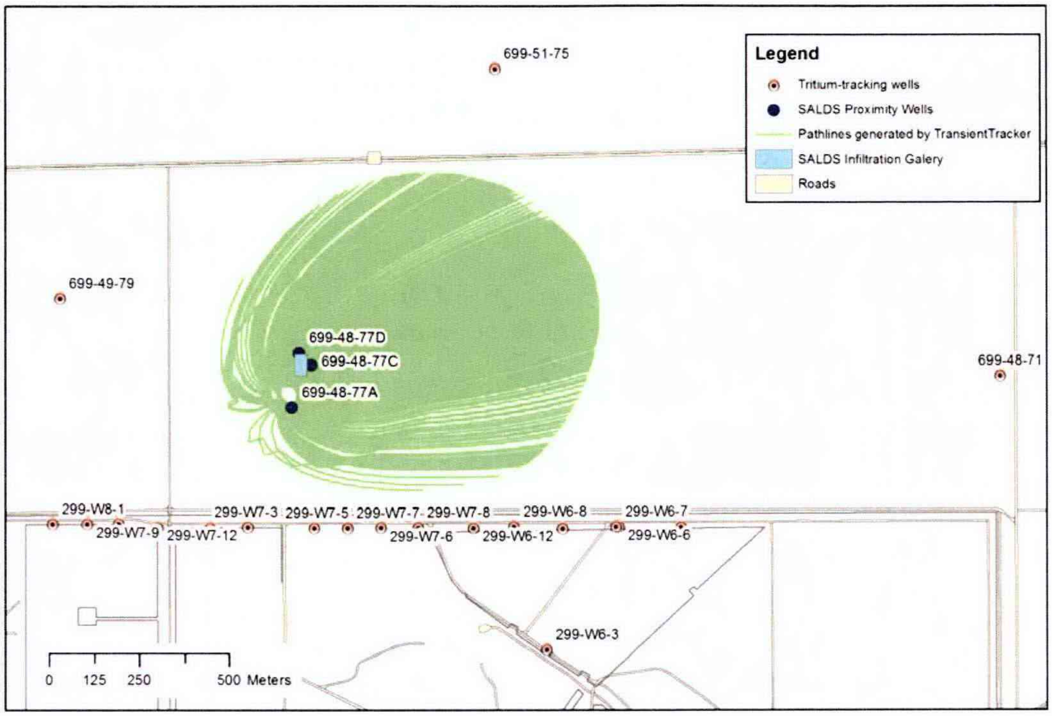

Figure B-1. Particle Traces Produced by Transient Tracker, a Utility of the KT3D_H2O Water-Level Mapping Program

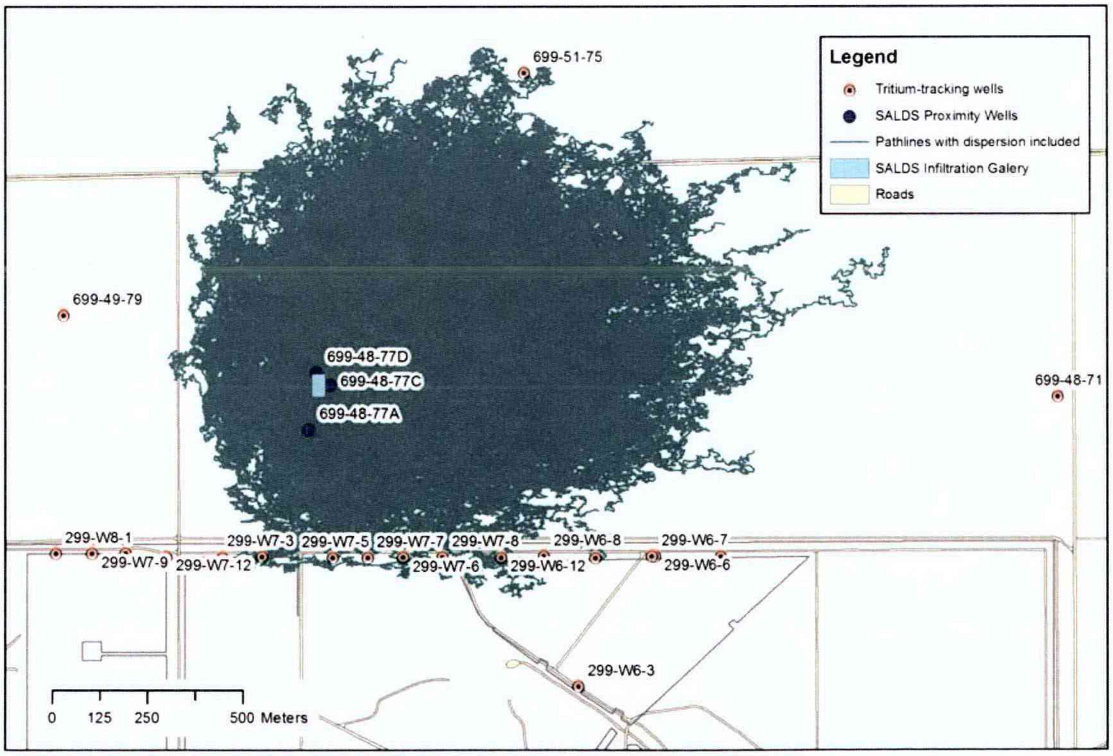

Figure B-2. Particle Traces Produced by Transient Tracker, a Utility of the KT3D_H2O Water-Level Mapping Program, Assuming Tritium is Subject to Dispersion

The Central Plateau model uses the U.S. Geological Survey code, MODFLOW-2000, to simulate groundwater flow, as illustrated in the following:

- "A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model" (McDonald and Harbaugh, 1988)
- *User's Documentation for MODFLOW-96, An Update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model* (Harbaugh and McDonald, 1996)
- *MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process* (Harbaugh et al., 2000)
- MODPATH to simulate particle paths (*User's Guide for MODPATH/MODPATH-PLOT, Version 3: A Particle Tracking Post-Processing Package for MODFLOW, the U. S. Geological Survey Finite-Difference Ground-Water Flow Model* [Pollock, 1994]).

In addition, the Central Plateau model uses MT3DMS to simulate contaminant migration (*MT3DMS, A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide* [Zheng and Wang, 1999]; *MT3DMS v5.3 Supplemental User's Guide* [Zheng, 2010]).

The groundwater modeling analysis was completed in three steps. First, the flow model was used to simulate groundwater flow in the vicinity of the SALDS from 1995 through 2030. During this period, actual (historic) and projected annualized fluid volume discharges from the SALDS were applied at the water table at the location identified from the superposition analysis (in addition to the historic wastewater discharges at all discharge locations throughout the 200 West and 200 East Areas that were already incorporated in the model [ECF-HANFORD-10-0371]). Throughout this period, groundwater extraction and injection at the adjacent 200-ZP-1 OU was included in the flow model, as described in SGW-47651. After groundwater flow modeling was completed, the results were used to complete particle tracking and reactive transport analyses.

B4.2 Particle Tracking

Particle tracking was performed using MODPATH (Pollock, 1994) to estimate the likely groundwater flow directions and tritium migration rates in the vicinity of the SALDS for comparison with rates obtained using the water-level mapping technique. This provided confidence that the model reproduces patterns obtained through the mapping analysis prior to performing reactive transport modeling.

Using the same particle starting locations, hydraulic conductivity, and mobile porosity used for the water-level mapping path-line analysis, particle tracking was performed by releasing particles concentrically around the estimated discharge location and tracking their migration through to 2030. Figure B-3 presents a comparison of the advection-only particle-tracking results obtained using MODPATH and the flow field calculated by MODFLOW, with the results obtained using the RK4 particle-tracking scheme on the mapped water-level surfaces. It is apparent from Figure B-3 that the two methods for calculating particle paths produce comparable results in terms of trajectory, distance travelled, and spread, although the particle paths calculated on the mapped surfaces travel and spread slightly farther than those calculated using MODPATH and the MODFLOW head solution. This may be due to the analytically continuous nature of the mapped surface versus the discretized nature of the MODFLOW solution, as well as the two-dimensional nature of the mapped surface versus the three-dimensional MODFLOW solution. Considering these structural differences in the methods, the comparison suggests that the groundwater model produces flow directions and rates that are suitable for use in reactive transport simulation of the fate of the injected tritium.

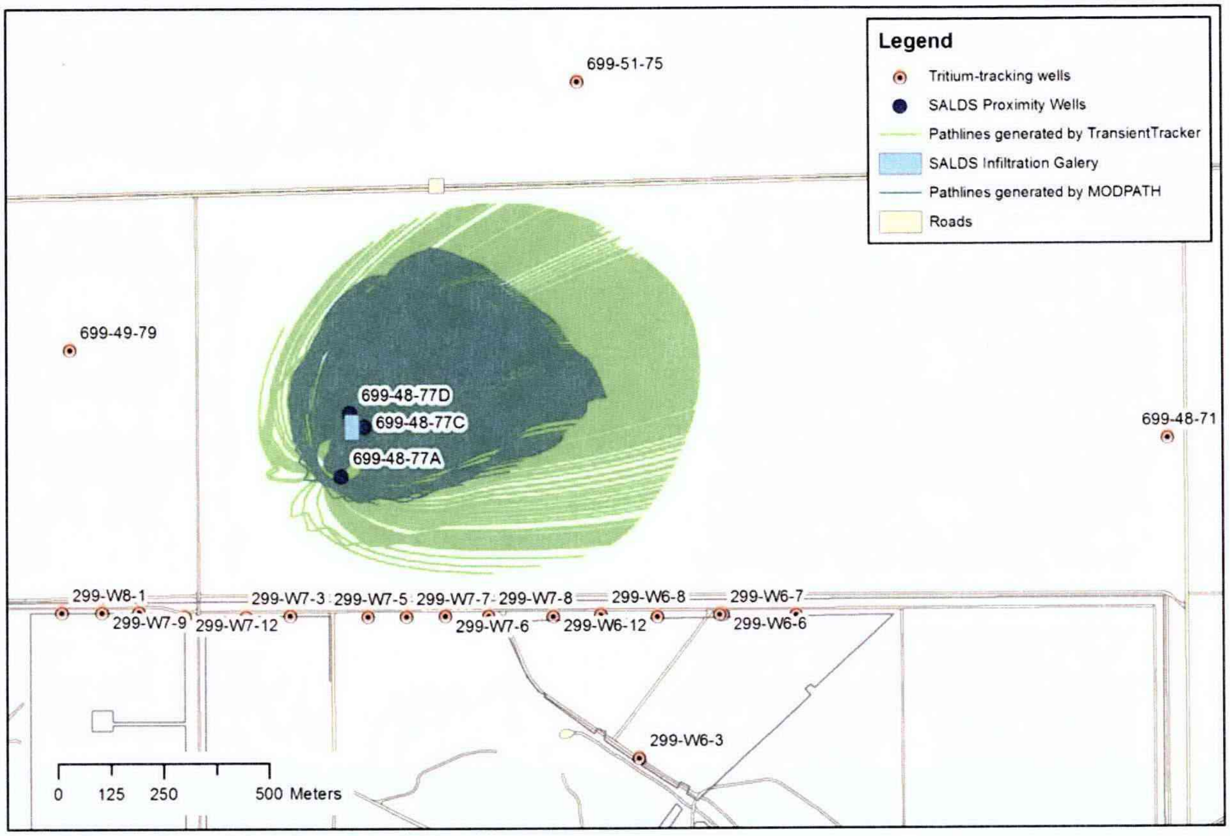

Figure B-3. Path Lines for 2030 Calculated using the Central Plateau Model (MODPATH) and Water-Level Mapping (Transient-Tracker)

B4.3 Reactive Transport Modeling

Reactive transport modeling provides estimates of tritium migration rates and the likely future distribution of tritium concentrations in groundwater in the vicinity of the SALDS.

The three-dimensional, multi-species transport model, MT3DMS (Zheng and Wang, 1999) was developed for use with MODFLOW to simulate advection, dispersion, and chemical reactions. MT3DMS was used to evaluate the approximate directions and rates of migration of the tritium injected at the SALDS facility. The simulations were performed using MT3DMS v5.2 (*MT3DMS v5.3: A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems – Supplemental User's Guide* [Zheng, 2006]) and the Central Plateau model flow results described above for the interval from 1995 through 2030. No effort was made to recalibrate this flow and transport model to the SALDS data prior to calculating the results presented in this appendix; however, the Central Plateau model was previously calibrated to heads measured in monitoring wells that are dominated by historic wastewater infiltration. For all simulations, the sole source of tritium considered was the SALDS facility, and the MT3DMS reaction package was used to simulate a half-life for tritium of 12.3 years. Dispersion was not explicitly considered in the transport simulations, although the implicit finite-difference scheme used to calculate the advective term of the transport equation may exhibit limited numerical dispersion. Two sets of transport simulations were performed, assuming effective (mobile) porosities of 0.13 and 0.18.

For the historic period, the fluid volume discharge to the SALDS was applied in the MODFLOW model using annual stress periods, resulting in annual average discharge volumes. However, the tritium discharged to the subsurface was simulated as a monthly averaged activity using the Hydrocarbon Spill Source (HSS) package developed for MT3DMS, which enables implicit loading of mass directly in to the model on an arbitrary time interval ("Recent Developments and Future Directions for MT3DMS and Related Transport Codes" [Zheng, 2009]; *MT3DMS, A Modular Three-Dimensional Multispecies Transport Model – User Guide to the Hydrocarbon Spill Source [HSS] Package* [Zheng et al., 2010]). This combination of annual average flows and monthly average tritium activities preserves the total mass (activity) discharged, and it reflects variations in tritium loading that persisted for relatively long periods of time (i.e., exceeding one month). As a result, the simulation results would be expected to match broad (longer term) changes in concentrations measured at monitoring wells but would not reflect localized (shorter term) changes in concentrations. For future timeframes, both the fluid volume discharge and tritium mass (activity) released were simulated as annual average values based upon projections provided by CH2M HILL Plateau Remediation Company. Two sets of results are presented as output from this simulation:

- Graphs of calculated tritium versus time under historic conditions, for which tritium loading at the SALDS is known and tritium concentrations are available at monitoring wells
- Maps of calculated tritium distribution in groundwater under future conditions, assuming projected tritium loading rates at the SALDS.

Figures B-4 through B-6 present measured and simulated tritium activities for wells 699-48-77A, 699-48-77C, and 699-48-77D, respectively, from the startup of SALDS discharges through 2009. These figures suggest that the flow and transport model reasonably reproduces the pattern of changes in tritium concentration at these proximal SALDS monitoring wells, reflecting the broader (longer term) concentration patterns and the timing of arrival and departure of major peaks (with the possible exception of well 699-48-77A). Differences in the simulated tritium at these wells from that presented in SGW-42604 reflect the effect of calibration and re-parameterization of the Central Plateau model during 2010 as described in ECF-HANFORD-10-0371, which was focused on broader aspects of the 200 West Area flow system and not on the SALDS facility. As expected, due to the method used for loading the fluid discharge to MODFLOW (annual average) and the discretization of the flow domain (100 m [328-ft] cell dimensions), the model does not reproduce relatively short-duration changes in tritium concentration. However, since the model reflects the broad patterns without explicit calibration, and the projected fluid and tritium discharge rates are annual averages, the model provides a suitable tool for making annual averaged projections of the future disposition of tritium in the subsurface from the SALDS.

Figures B-7 through B-13 present the simulated tritium distribution in groundwater (model layer #1, as described in ECF-HANFORD-10-0371) in years 2005, 2010, 2015, 2020, and 2025, respectively, as a result of SALDS operations. Each figure presents two simulated depictions, calculated assuming effective (mobile) porosities of 0.13 and 0.18, respectively. The results of these simulations are generally consistent with those presented in previous reports (e.g., PNNL-14898) in terms of size, orientation, and concentration pattern of tritium in the water table aquifer. Again, differences in the simulated disposition of tritium in groundwater from that presented in SGW-42604 reflect the effect of calibration and re-parameterization of the Central Plateau model during 2010 as described in ECF-HANFORD-10-0371, which was focused on broader aspects of the 200 West Area flow system and not on the SALDS facility.

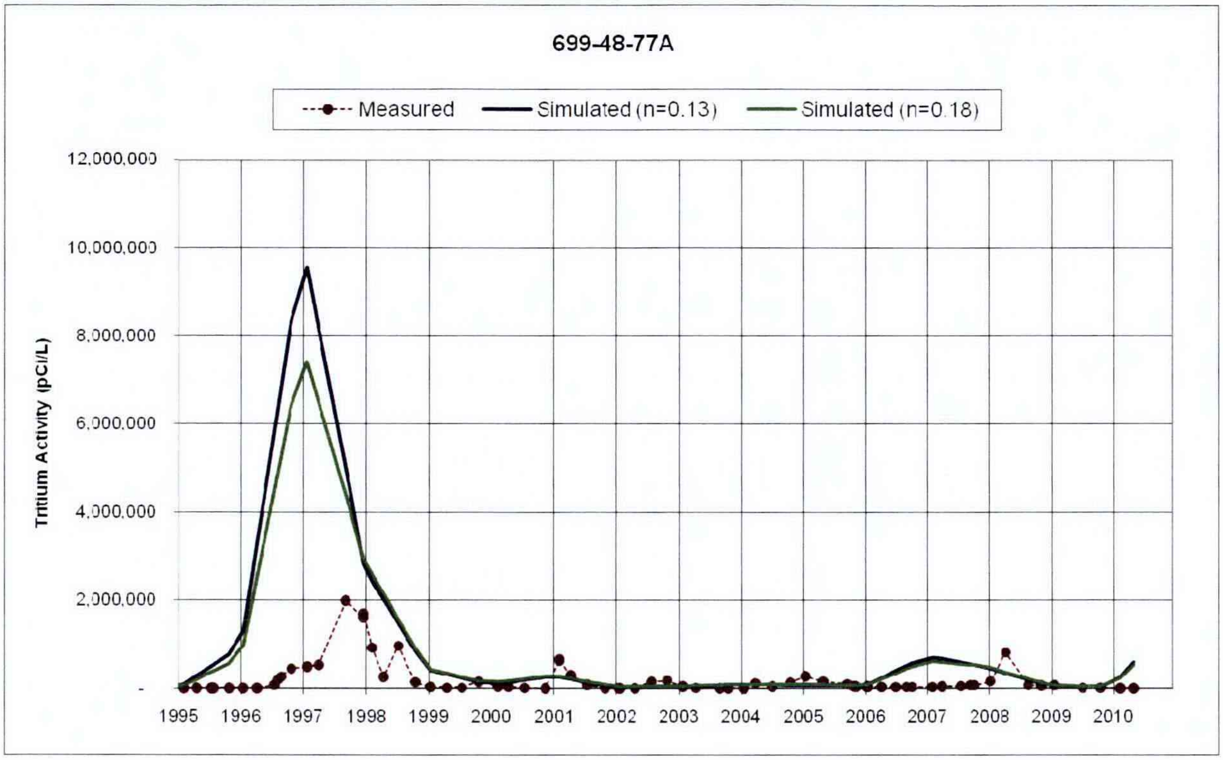

Figure B-4. Simulated and Modeled Tritium Activities for Well 699-48-77A

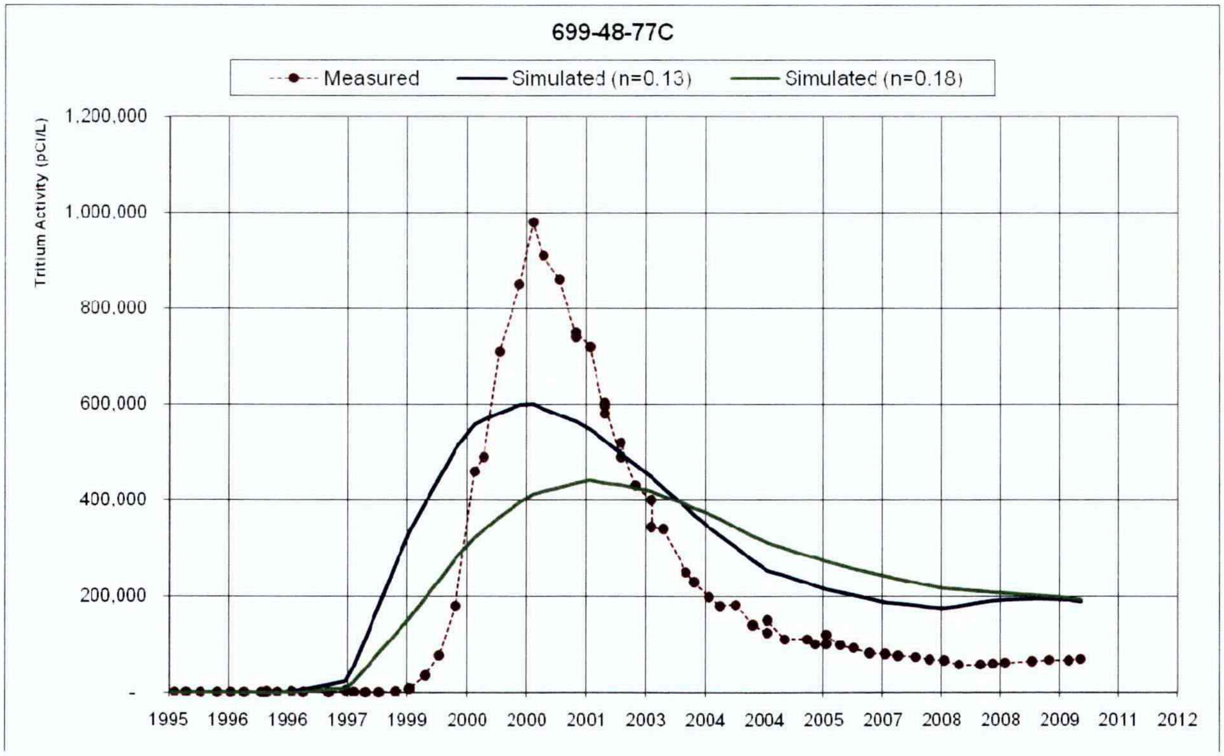

Figure B-5. Simulated and Modeled Tritium Activities for Well 699-48-77C

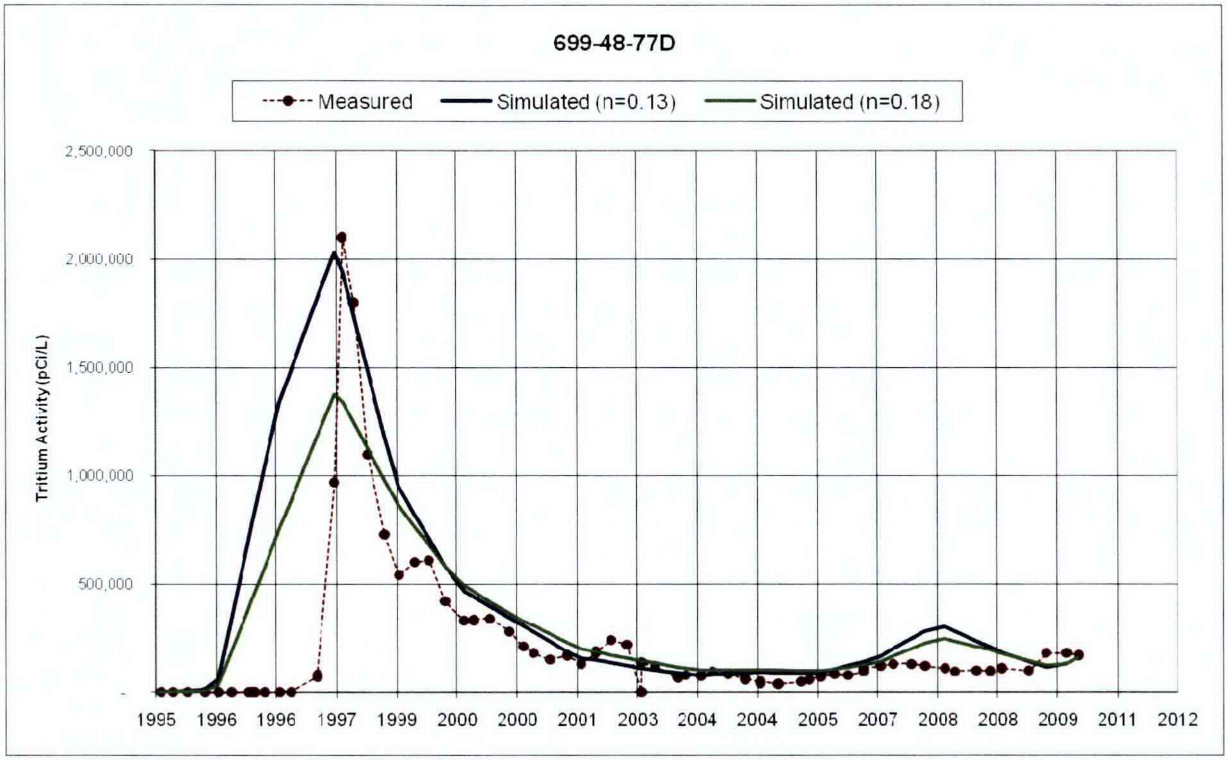

Figure B-6. Simulated and Modeled Tritium Activities for Well 699-48-77D

B4.4 Evaluation of Monitoring Well Screen Intervals

As described in "Identifying the Potential Loss of Monitoring Wells Using an Uncertainty Analysis" (Freedman et al., 2005), declining water levels throughout the 200 West Area that result from termination of historic wastewater infiltration will, over time, lead to the screened intervals of a number of monitoring wells lying above the water table. As a result, it will not be possible to measure water levels or obtain groundwater samples from these wells. Previous evaluations of the impact of discharges at the SALDS, including the most recent (SGW-42604), provided estimates of the likely decline in water levels at monitoring wells in the vicinity of the SALDS based upon analyses of measured water-level trends in recent years at those wells. This approach provides a reasonable estimate of the likely decline in water levels under the assumption that there are no significant changes expected in groundwater conditions.

Groundwater levels in the vicinity of the SALDS are expected to change in response to extraction and injection associated with the expanded 200-ZP-1 groundwater pump-and-treat remedy described in the *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington* [EPA et al., 2008]). The configuration of extraction and injection wells that is described in the *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan* (DOE/RL-2008-78), and simulated in DOE/RL-2009-38, indicates that water levels in the vicinity of the SALDS will be impacted by both extraction and injection, with a net impact that will depend on location and the final remedy implementation.

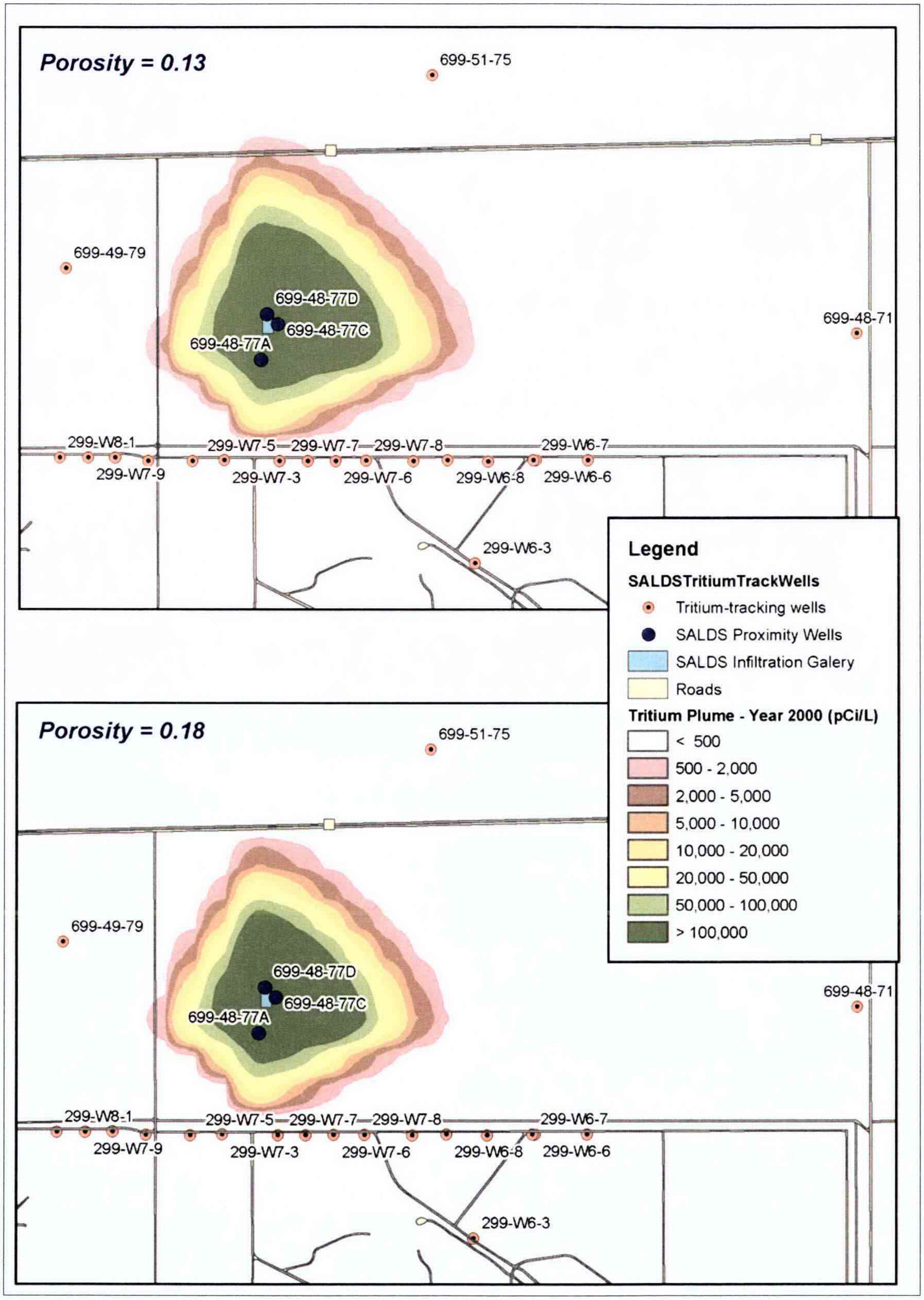

Figure B-7. Simulated Tritium Distribution as a Result of SALDS Operation in Year 2000

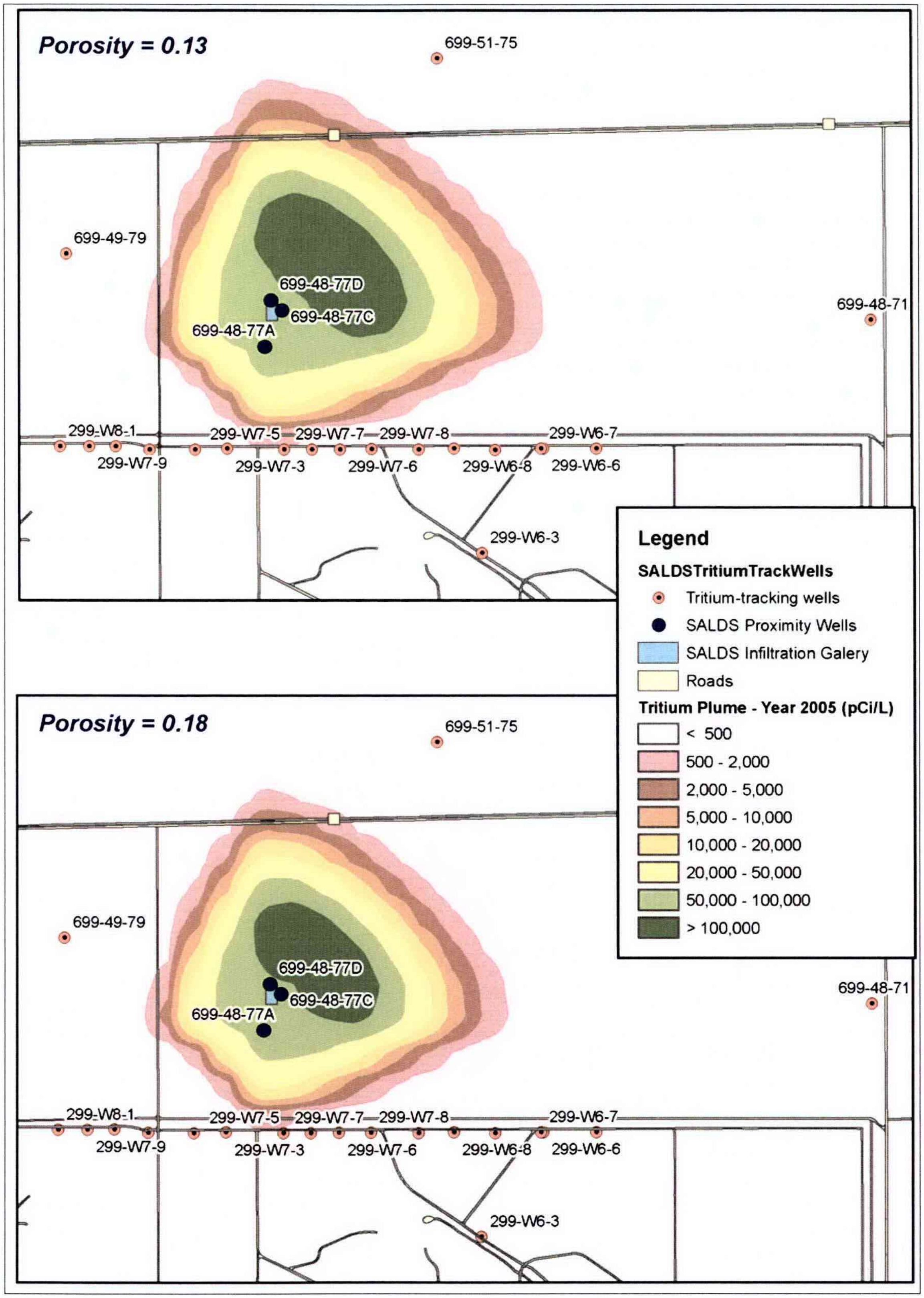

Figure B-8. Simulated Tritium Distribution as a Result of SALDS Operation in Year 2005

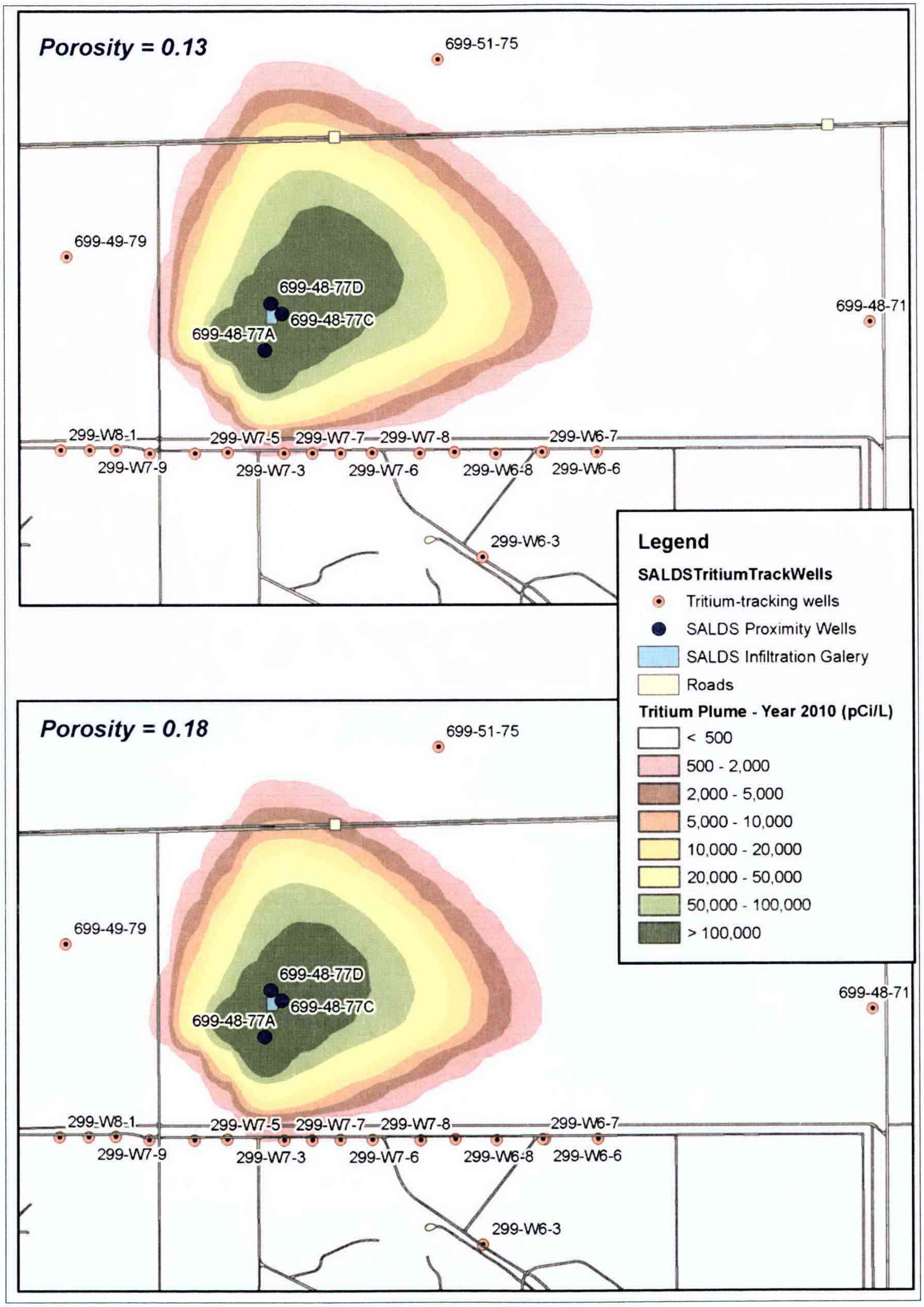

Figure B-9. Simulated Tritium Distribution as a Result of SALDS Operation in Year 2009

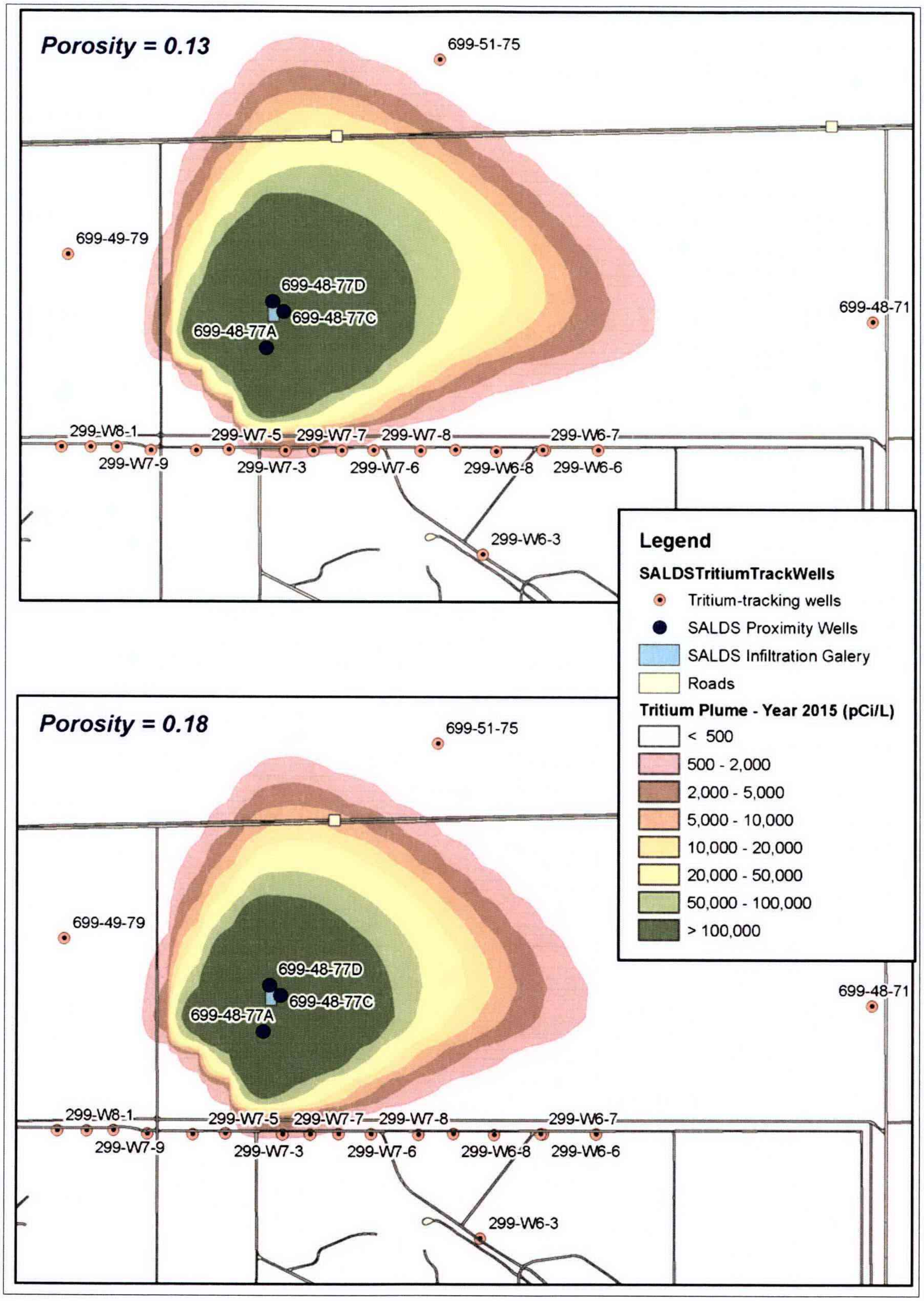

Figure B-10. Simulated Tritium Distribution as a Result of SALDS Operation in Year 2015

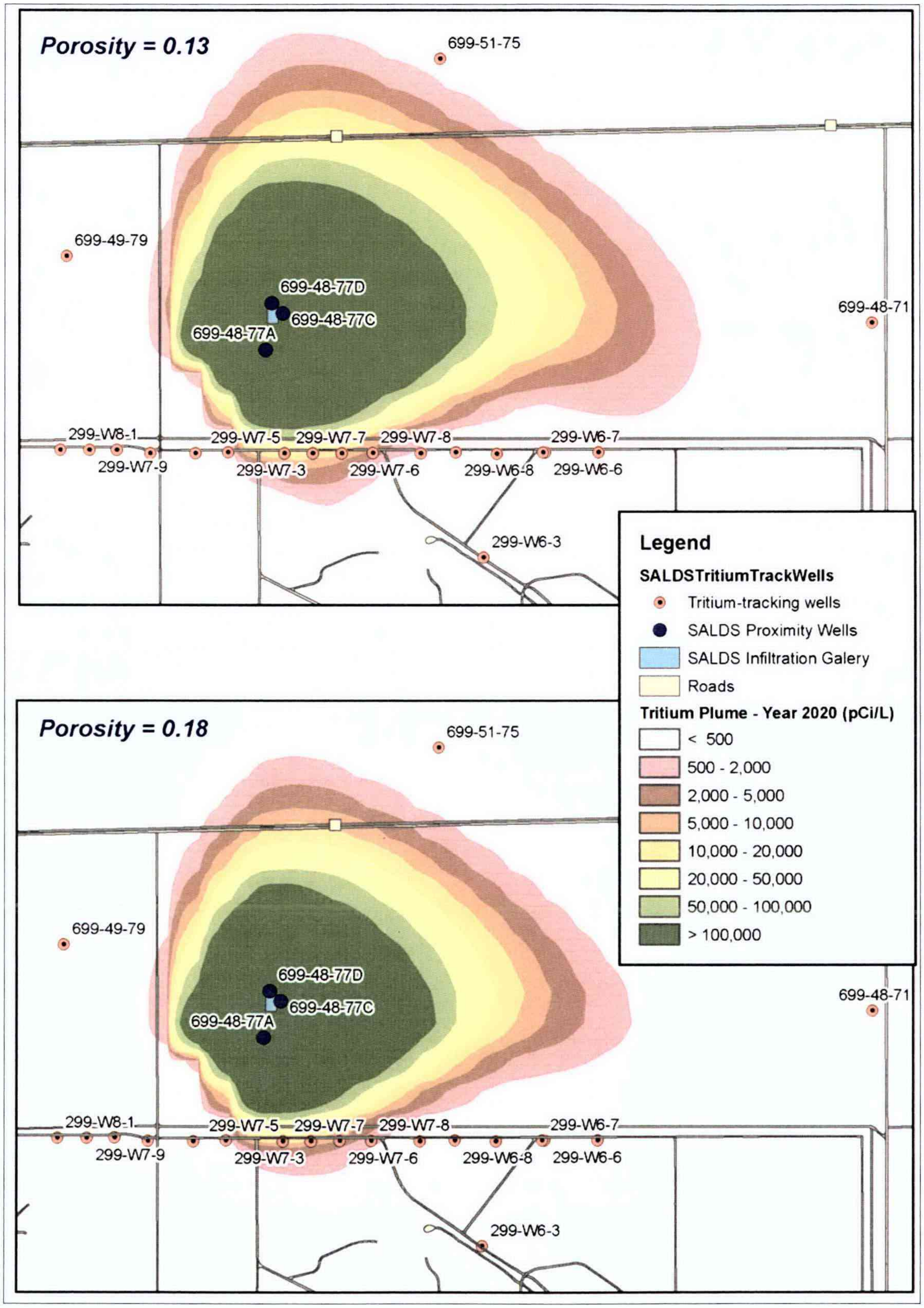

Figure B-11. Simulated Tritium Distribution as a Result of SALDS Operation in Year 2020

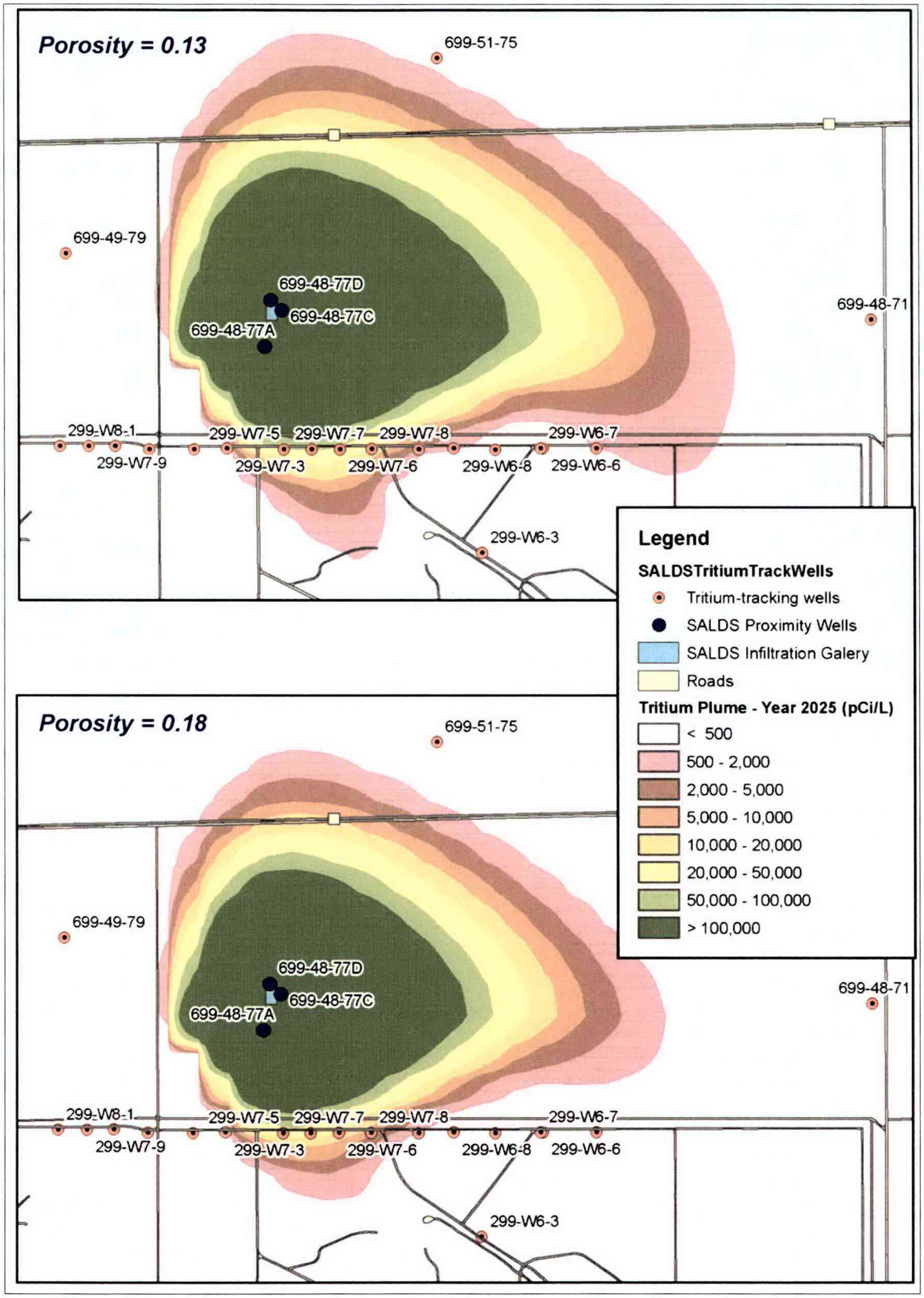

Figure B-12. Simulated Tritium Distribution as a Result of SALDS Operation in Year 2025

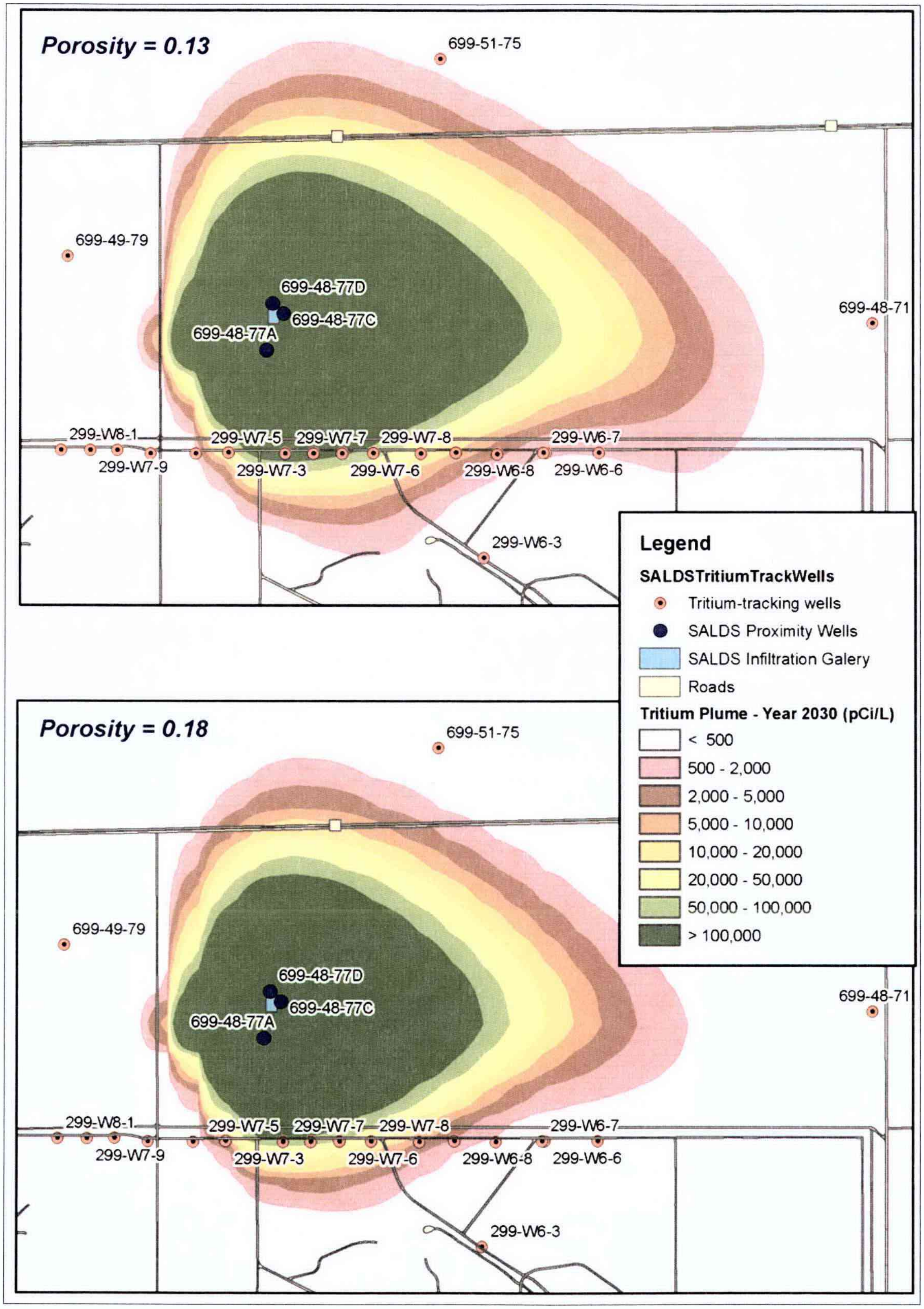

Figure B-13. Simulated Tritium Distribution as a Result of SALDS Operation in Year 2030

Figure B-14 depicts measured, projected, and simulated water levels at three of the principal SALDS monitoring wells (699-48-77A, 699-48-77C, and 699-48-77D), as well as the top and bottom elevation of the well screen. The measured water levels are available through June 2010, the projected water levels are calculated using a least-squares trend-line fit to the last 10 years of data recorded, and, the simulated water levels are calculated using the Central Plateau model Version 3 (ECF-HANFORD-10-0371). Noting that to-date calibration of the Central Plateau groundwater model has focused on wider area patterns throughout the Central Plateau, and that the three wells of interest (699-48-77A, 699-48-77C, and 699-48-77D) are located close together, the following is evident from Figure B-14:

- Recent water-level data suggest that well 699-48-77A is nearly dry, well 699-48-77C (a deep well) has over 30 m (98 ft) of water column above the screen bottom, and well 699-48-77D has approximately 2 m (6.6 ft) of water column above the screen bottom.

- Projected water levels for well 699-48-77C, calculated using either the Central Plateau model or a least-squares trend-line fit to recent data, suggest that this well screen will remain below the water table (and as a result, possible to sample) for many years.

- Water-level projections for well 699-48-77A calculated using the Central Plateau model incorporate the possible effects of future groundwater extraction and injection. The water-level projections suggest that water levels may increase at this well following startup of the 200-ZP-1 OU remedy, which may extend the life of this well by about 2 years or more. It is noted that water levels simulated by the current Central Plateau model correspond most closely with the measured levels at well 699-48-77A.

- Water-level projections for well 699-48-77D calculated using a least-squares trend-line fit to recent data suggest that this well screen will be above the water table (and as a result, not possible to sample) late in 2012. Water-level projections for this well calculated using the Central Plateau model, which incorporate the possible effects of future groundwater extraction and injection, suggest that water levels may increase at this well following startup of the 200-ZP-1 OU remedy, which may extend the life of this well by about 2 years or more.

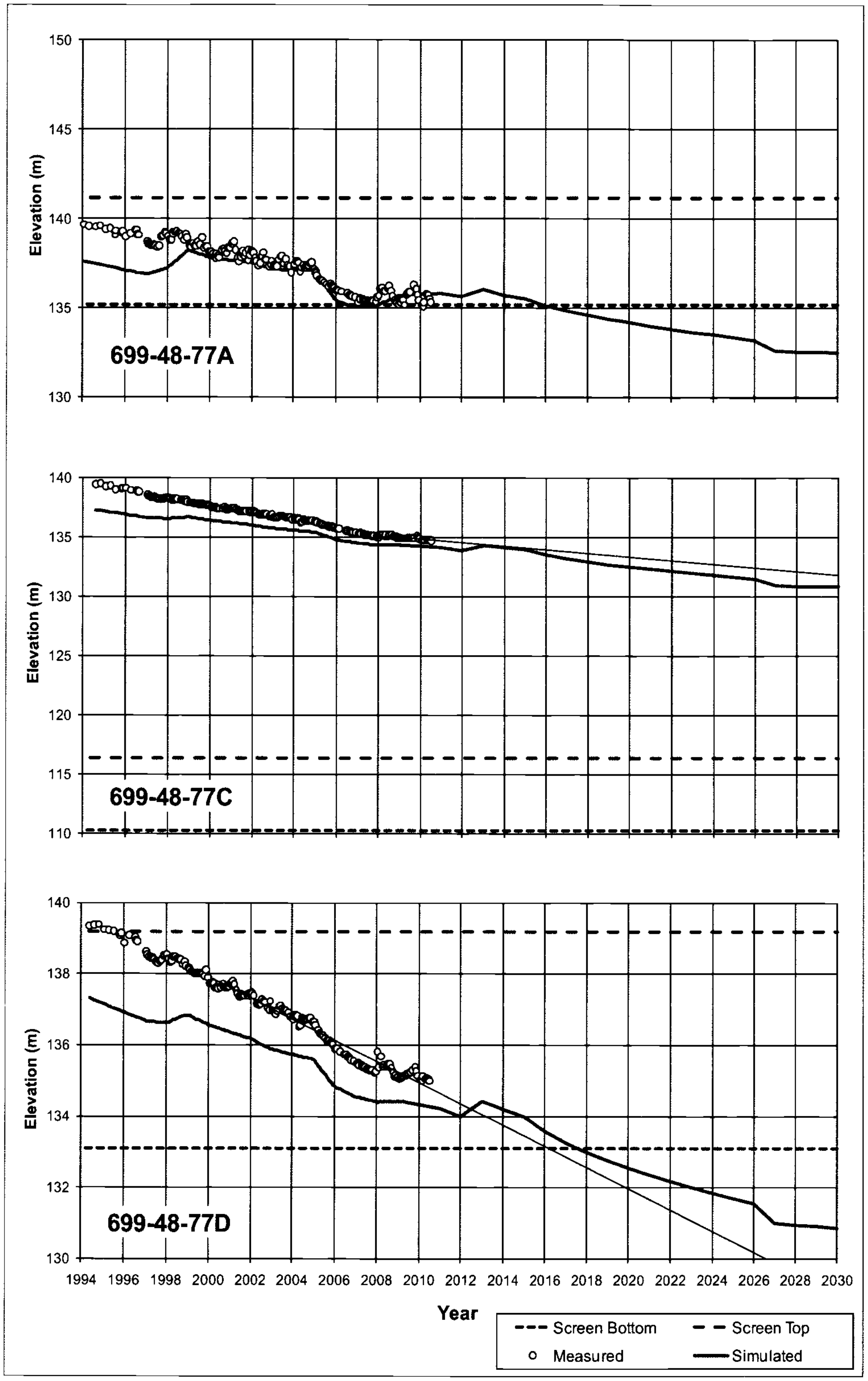

Figure B-14. Measured, Projected, and Simulated Water Levels at Wells 699-48-77A, 699-48-77C, and 699-48-77D

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Appendix C

Software Installations

Contents

C Software Installations

Software use for this calculation was in accordance with PRC-PRO-IRM-309, *Controlled Software Management.*

C1 Approved Software

The following software was used to perform calculations and was approved and is compliant with PRC-PRO-IRM-309. The software is managed under the following documents consistent with PRC-PRO-IRM-309:

- CHPRC-00257, Rev. 1, *MODFLOW and Related Codes Functional Requirements Document*
- CHPRC-00258, Rev. 2, *MODFLOW and Related Codes Software Management Plan*
- CHPRC-00259, Rev. 1, *MODFLOW and Related Codes Software Test Plan*
- CHPRC-00260, Rev. 2, *MODFLOW and Related Codes Acceptance Test Report*
- CHPRC-00261, Rev. 1, *MODFLOW and Related Codes Requirements Traceability Matrix.*

CHPRC-00258 distinguishes between safety software and support software based on whether the software managed calculates reportable results or provides run support, visualization, or other similar functions. Brief descriptions of the software are provided in the following subsections.

C1.1 MODFLOW (Controlled Calculation Software)

- Software title: MODFLOW-2000 (*MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process* [Harbaugh et al., 2000]); solves transient groundwater flow equations using the finite-difference discretization technique.

- Software version: Version 2.1.18, modified by S.S. Papadopulos and Associates, Inc., for minimum saturated thickness and using the Orthomnin solver; approved as CH2M HILL Plateau Remediation Company (CHPRC) Build 0003 using executable "mf2k-mst-0003dp" (compiled to default double precision for real variables).

- Hanford Information Systems Inventory identification number: 2517 (safety software, graded Level C).

- Workstation type and property number (from which software is run): S.S. Papadopulos and Associates, Inc., PC #FE404.

C1.2 MT3DMS (Controlled Calculation Software)

- Software title: MT3DMS (*MT3DMS, A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide* [Zheng and Wang, 1999]; *MT3DMS v5.3: A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems – Supplemental User's Guide* [Zheng, 2006]).

- Software version: Version 5.2, modified by S.S. Papadopulos and Associates, Inc., for minimum saturated thickness; approved as CHPRC Build 0003 using executable "mt3d-mst-0003dp" (compiled to default double precision for real variables).
- Hanford Information Systems Inventory identification number: 2518 (safety software, graded Level C).
- Workstation type and property number (from which software is run): S.S. Papadopulos and Associates, Inc., PC #FE404.

C1.3 Support Software

Supporting programs were used to complete the Central Plateau model simulations described in this document. These supporting programs are described in *Central Plateau Version 3 MODFLOW Model* (ECF-HANFORD-10-0371) and comprise the following utilities to pre- and post-process the flow and transport model input and output files, respectively:

- ALLOCATEQWELL: Constructs a MODFLOW well package (WEL) or a multi-node well (MNW) package file.
- READ-LST-BUDGET: Tabulates volumetric budget terms for the MODFLOW simulation.
- READ-MT3D-OUT-BUDGET: Tabulates mass budget terms for the MT3DMS simulation.

With the exception of the tritium concentration data, all inputs to the Central Plateau model used in the calculations presented here are identical to those described in ECF-HANFORD-10-0371.

C2 Software Installation and Checkout

The software identified above was used consistent with intended use for CHPRC as identified in CHPRC-00257, and this is a valid use of this software for the problem addressed in this application.

The software was used within its limitations as identified in CHPRC-00257.

C3 References

CHPRC-00257, 2010, *MODFLOW and Related Codes Functional Requirements Document*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00258, 2010, *MODFLOW and Related Codes Software Management Plan*, Rev. 2, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00259, 2010, *MODFLOW and Related Codes Software Test Plan*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00260, 2010, *MODFLOW and Related Codes Acceptance Test Report*, Rev. 2, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00261, 2010, *MODFLOW and Related Codes Requirements Traceability Matrix*, Rev. 2, CH2M HILL Plateau Remediation Company, Richland, Washington.

ECF-HANFORD-10-0371, 2010, *Central Plateau Version 3 MODFLOW Model*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://www2.hanford.gov/arpir/?content=findpage&AKey=0084305.

Harbaugh, Arlen W., Edward R. Banta, Mary C. Hill, and Michael G. McDonald, 2000, *MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*, U.S. Geological Survey Open-File Report 00-92, U.S. Geological Survey, Reston, Virginia. Available at: http://water.usgs.gov/nrp/gwsoftware/modflow2000/ofr00-92.pdf.

PRC-PRO-IRM-309, 2009, *Controlled Software Management*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

Zheng, Chunmiao, 2006, *MT3DMS v5.3: A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems – Supplemental User's Guide*, Technical Report to the U.S. Army Engineer Research and Development Center, Department of Geological Sciences, University of Alabama, Tuscaloosa, Alabama. Available at: http://hydro.geo.ua.edu/mt3d/mt3dms_v5_supplemental.pdf.

Zheng, Chunmiao and P. Patrick Wang, 1999, *MT3DMS, A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*, Report SERDP-99-1, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. Available at: http://hydro.geo.ua.edu/mt3d/mt3dmanual.pdf.

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